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ACHIEVE LEARNING OBJECTIVES, PAPERS PREPARED ESPECIALLY FOR A SUMMER INSTITUTE ON EFFECTIVE TEACHING FOR YOUNG ENGINEERING TEACHERS (PENNSYLVANIA STATE UNIVERSITY, AUGUST 28 THROUGH SEPTEMBER 3, 1960.

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PAPERS PREPARED FOR A SUMMER INSTITUTE ON EFFECTIVE TEACHING FOR TEACHERS OF ENGINEERING SUBJECTS ARE CONTAINED IN THIS CONFERENCE REPORT. GENERAL SUBJECT AREAS DISCUSSED ARE--(1) EDUCATIONAL OBJECTIVES IN ENGINEERING EDUCATION, (2) LEARNING THEORY AND ITS APPLICATION TO CLASSROOM TEACHING, (3) LECTURE, DISCUSSION, AND LECTURE-DISCUSSION METHODS OF TEACHING, (4) THE USE OF AUDIOVISUAL AIDS, (5) THE ROLE OF THE LABORATORY IN ENGINEERING EDUCATION, (6) STUDENT AND INSTRUCTIONAL EVALUATION, (7) THE PLANNING OF COURSES, CURRICULUMS, AND INDIVIDUAL LESSONS, (8) THE STIMULATION OF STUDENT CREATIVITY, (9) RESEARCH IN ENGINEERING EDUCATION, AND (10) PROFESSIONAL DEVELOPMENT. A COMPREHENSIVE ANNOTATED BIBLIOGRAPHY IS INCLUDED. (AG)

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Otis E. Lancaster, Director
University Park, Pennsylvania
September, 1960

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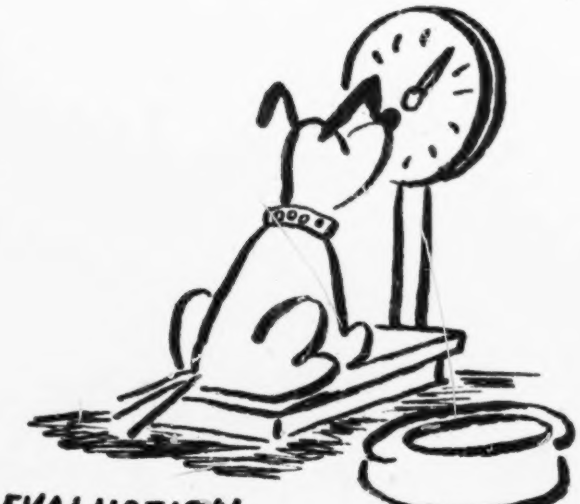

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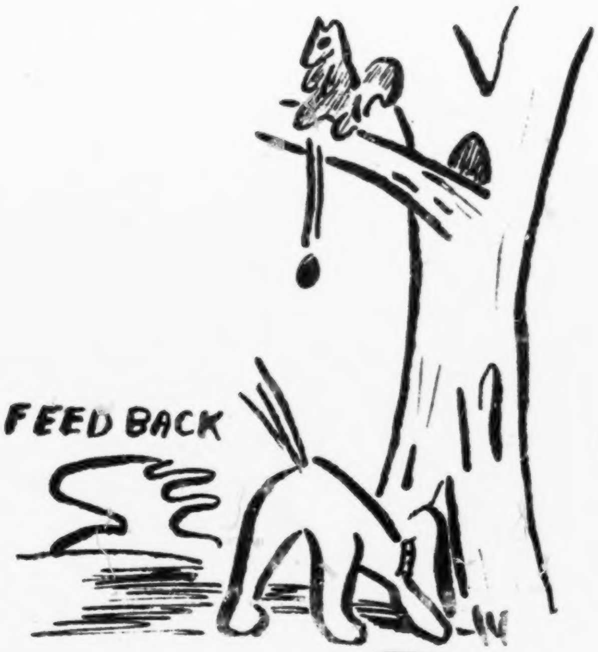

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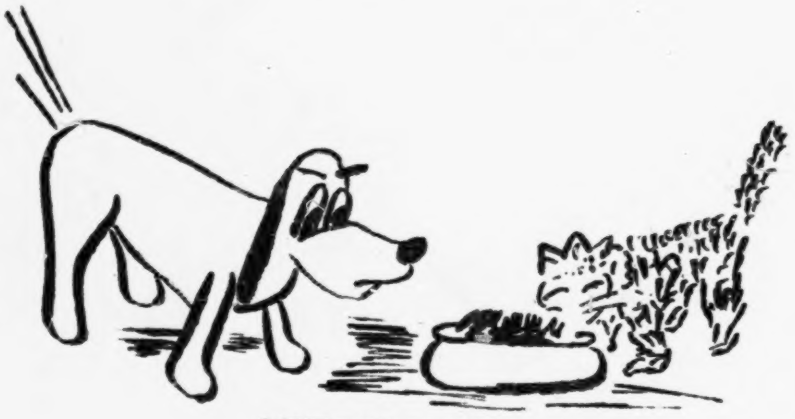

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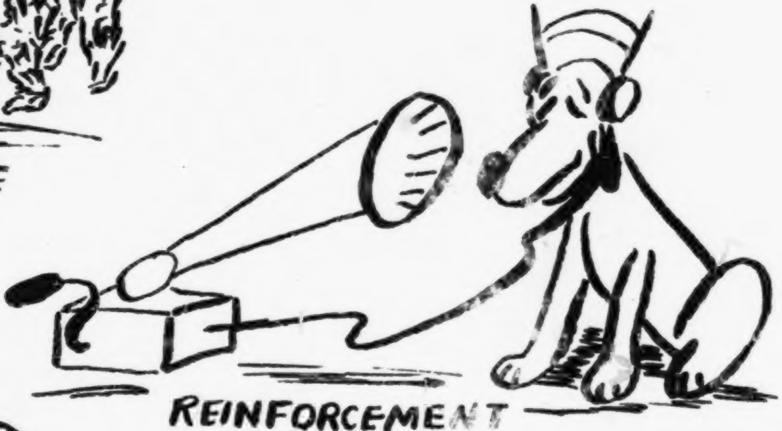

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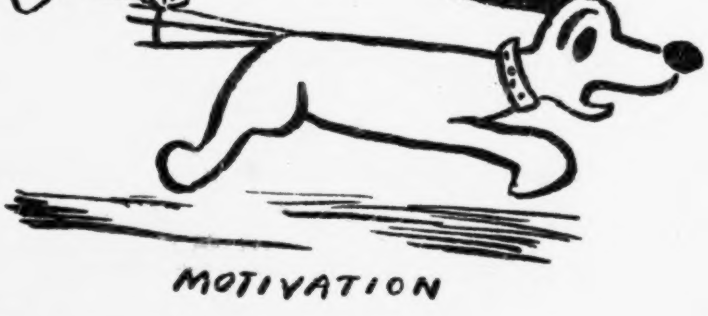

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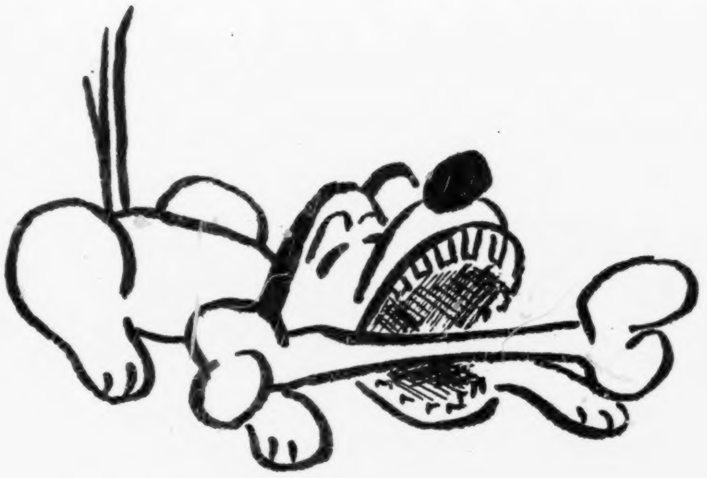

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CREATIVITY

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INTRODUCTORY AND WELCOME ADDRESS TO THE SUMMER INSTITUTE ON EFFECTIVE TEACHING FOR YOUNG ENGINEERING TEACHERS

Dr. Eric A. Walker, President
The Pennsylvania State University

I want you to know that I'm delighted to have this opportunity to meet with you this morning to say "hello" and to welcome you to our campus. I am delighted not only because I'm glad to welcome you to Penn State - - you are warmly welcome - - but also because I'm very pleased to see this operation get under way. For ten years now I have been saying that engineering teachers ought to do more worrying about teaching. Consequently, I was pleased when I heard that Otis Lancaster and Dick Teare had organized this institute, and I'm glad to have a chance to participate in it, however slightly.

I think one of the most startling conversations I ever had in my life occurred during the war years when we were organizing the ESMWT programs. I went to the state teachers' college of the state where I was working at that time and asked if we could get any help in teaching courses in Electrical Engineering, thinking that perhaps it could lend us some people to teach courses in English, elementary math, and the like. The president of the college said to me, "Oh, yes, my teachers can teach anything. They are professional teachers. They know the methods of teaching; therefore, they can teach electrical engineering." And he meant it.

Yet you must remember that we do just the opposite. We say that as long as a person knows the subject matter, he can teach it. Is this really any more sound than the opposite position? When I remember that almost no professors have had any more training in teaching than that involved in listening to both good teaching and bad, I know that a good many of our professors haven't the foggiest idea how to design an examination. They don't realize, for instance, that some examinations are like plug gauges: they're either "go" or "no go." Others are like taper gauges: they allow a teacher to plot a distribution curve with gradients.

When many of our teachers have never even seen a learning curve or a forgetting curve, I cannot help but wonder whether we are really paying attention to our main business? Yet I now know that engineering educators are doing more about this than any other group. Perhaps this is true because engineering educators seem to have less fear of technological unemployment than do other teachers. This fear is a very real thing among many teachers at all levels. These teachers seem to fear any new idea because it might put them out of their jobs.

Through the years, many new mechanisms and devices have been invented that seemed to threaten teachers' existence. I'm sure the first teachers were just story tellers. Then somebody invented writing. I expect the story-tellers union, if there was one and there probably was, thought this was going to put all story tellers out of business. Why listen if you could read it in writing? Then, of course, came the movable type and printing. This was expected to put all the scribes out of business, but it didn't. I remember that, when radio came out, there was some apprehension that it would eliminate all teachers because, with radio, one teacher could transmit all the information that was taught. We're now going through the same thing with television. Many people are afraid of television teaching because, again, they think it will put the teachers out of business.

Despite all this addition of mechanisms and devices, insofar as I can see there have been only two new ideas about teaching in all recorded history. One was Socrates' idea of making teaching an argumentative process. He made it a competition. Instead of teaching by story telling, he taught the students to argue about things. This, I think, was the first new and good idea about teaching. The second one - - and I don't know who invented this one - - was the demonstration method involving the use of a laboratory experiment as part of the lesson.

If these are the only two new ideas we've had - - as I believe they are - - the field is certainly wide open for some good ideas. The problem of good teaching is a real problem for educational administrators everywhere. We are constantly and continually accused of not recognizing good teaching. And I'm sure these accusations are well founded. I admit that I don't know how to recognize good teaching. I can recognize good administration.

This is my job. And I can design a test to see if a man is a good administrator. I can recognize good research: all I have to do is look at a man's publications, note where they were published, and observe how many times they are noted in the footnotes of subsequent papers. I can tell what's good research. But there's almost no way to assess a man's work to say "He's a good teacher," and have it reflected in his paycheck.

As you know, some people say "Ask the students." And I'm sure some students do recognize good teaching. Let me tell you this. When I ask our older alumni, "Who was the best teacher at Penn State when you were here?" they all tell me it was "Swampy" Pond, a professor of chemistry. Well, a couple of years ago I took the time to look back into the student newspapers of the days when "Swampy" Pond was a teacher here. He was the most hated man on the campus. His method of teaching was such that it hardly endeared him to the students. Now, thirty years after, they think he was the best teacher they ever had. I'm sure this is true. Generally, many good teachers are not really loved by the students they are teaching at any one time.

What other measures could we use? Well, we could separate the examining function from the teaching function. I often think this is one of the strongest things about the English Universities. One man teaches; another man examines. With this arrangement, you've got a method of measuring the value of a teacher over a period of time. We tried a "stunt" here at Penn State that seems to me to be worth considering: we asked the honor students who had been graduated three years earlier "Who was the best teacher you had at Penn State?" And there seems to be considerable validity for this sort of thing because the results seemed to indicate that the best students recognize the best teachers after they've had time to mellow and forget some of their teachers' idiosyncrasies.

Of course, there's always the method of direct observation. But, in many of our departments, if I were to propose teacher evaluation through observation - - by actually visiting classes - - the teacher would rebel. I can only comment that something must be wrong when a professional worker is ashamed to have people watch him in operation - - watch him doing the things he is supposed to know how to do.

As I said, we've been talking now for ten years about having ASEE do something about its main business - the business of education. We talked about having the Educational Methods Division do something. We talked about having the Research Council do something, since research is involved. As you may hear later, we now expect to try to do something more than we have been doing in the past. The Society now finds itself sponsoring a great many research projects. Yet we've done it sort of backwards: people come to us and say "Here's a research project. Would the ASEE sponsor it?" Sometimes ASEE has been able to help with these projects and sometimes it has not. Then, too, there is the operation that Harold Foecke has been running for the past couple of years. This has been a very successful operation, but it was carried out as a sort of a side issue by the Society.

To organize ASEE efforts in this area, Dick Teare proposed last year that we put together a group of people to manage projects. We are just about ready to get it off the ground. We're going to call it the Projects Management Group. This group will try to initiate projects in research in our main business and then to get some foundation support for those projects. We hope to get PMG started this year in order to involve the Society in its main businesss - - the improvement of engineering education.

I'm sure that this conference - - the conference that you are attending here today - will be very productive - - and productive on one of the most important things about which we must be productive - - that is, how to produce better engineers and more engineers. I should like to repeat: I am very glad to see you here. I am glad that this conference is being held at Penn State. Here at Penn State, we've had some pretty good engineering teachers: men like Sackett and Hammond. If they could look down on this group, I think they would say that this is a good thing for Penn State to do. So, I'm glad to be here to welcome you. Best wishes for a truly successful meeting!

August 29, 1960

OBJECTIVES IN ENGINEERING EDUCATION

B. R. Teare, Jr.
Carnegie Institute of Technology

It is a great pleasure to me to be participating in this opening session of a summer institute that I believe will be very significant in engineering education. We engineers are tremendously interested in pushing back the frontiers of our field; that is, in creating bigger, more complicated, more efficient and less costly products, some of which serve entirely new needs of man, and we are keenly interested in the philosophy of engineering itself. However, we do not seem to be making the same kind of progress in the conception and practice of teaching that we make in the field that we teach. I have heard it said that engineering education is one of the few professions for which there is no formal preparation, and the extent of truth that there is in this statement may account in part for a slow rate of advance. We teachers tend to start from scratch, ignoring a large part of what has been done before and somehow not undertaking much new, significant research in teaching methods.

This is so in spite of our having a unique society devoted to engineering education, ASEE. This society has served our profession by stimulating and publishing many good papers; it has singly and jointly with others produced excellent statistical studies of our activities; and, what is probably most important, it has sponsored a number of very worthwhile projects which I should like to mention in some detail later. However, there seems to be a wide gap between what has been written and what is practiced in the classroom. This is why I think the present institute can contribute significantly by finding ways to help beginning teachers to think seriously and professionally about the education part of the profession of engineering education. And of course the logical starting place is the consideration of objectives.

A clear definite goal is as necessary in the teaching of engineering courses as in any other kind of engineering work. Everything the teacher does, planning a one-hour recitation or a three-hour laboratory period, designing homework assignments, devising examinations, planning a whole course, or even building curricula cannot be done rationally and systematically without thinking in terms of objectives. These planning activities all involve choices of alternatives, and choices cannot be made sensibly without having some standard, something in terms of which the alternatives can be evaluated. My thesis here is that the planner should select that alternative which best serves the objectives, and thus it is necessary to set these first and to understand them thoroughly. The objectives may be chosen by the teacher himself, but in their full breadth they have to be set by the faculty or by the institution as a whole. However, it is clear that no matter what the stated purposes of the institution may be, unless a teacher firmly believes in them and is fully conscious of them, they will not influence his teaching and they might just as well not exist at all, as far as his teaching is concerned. What the teacher consciously or unconsciously believes to be important determines, of course, what he will teach.

It is easy to pontificate in this matter of objectives and to leave you only with general ideas and no clear picture of what they mean. I prefer to get down to earth by talking about a relatively simple situation, one of the simplest that I can think of, one that actually occurred, and which made a great impression on me. Some years ago, a group of teachers, of which I was one, was dissatisfied with the educational effectiveness of our laboratories. This happened to be in electrical engineering, but electrical laboratories have much in common with other engineering laboratories so I think that this will serve to illuminate the matter of objectives, no matter what the field. We began by questioning the choice of experiments, some of which were of the routine kind found in laboratory manuals, experiments such as determining the families of speed torque characteristics for several kinds of machines, or the vacuum tube characteristics for a number of different kinds of tubes--diodes, triodes, pentodes, thyratrons and so on. And then we went on to question whether the student was given instructions in too complete form, and whether the required reports took too much time without contributing efficiently to genuine education, and whether the methods of examining and grading were appropriate and so forth. This happened to occur some time ago, but unless education has advanced further than I think it has, I am sure that many of these problems still exist.

In trying to deal with these problems of teaching in the laboratory we immediately ran head on into the question of objectives; one set of objectives leads to one kind of laboratory, another set to a different kind of laboratory. We found that we could not proceed very far without settling upon objectives, but once they were determined it appeared that it would be relatively easy to choose the best of the alternative subjects and alternative methods for the laboratory. However, when we tried to set down our objectives somewhat formally, we realized that we needed to do a lot of thinking.

One of the first objectives that was suggested was the natural one, that the purpose of the laboratory should be the obtaining of experimental data. But, after some discussion, this was completely rejected as a major goal; it was held to be only a very minor one or perhaps relevant merely as a means to some other end. For, whoever turns to his own laboratory reports on standard types of equipment to find out what their characteristics are? Any need we have for machine and tube data is much better served by textbooks and handbooks than by our own reports.

No, I am sure that the main purpose of a laboratory problem is not to get data, although there is some merit in considering that learning how to get data, is an objective.

Other suggested objectives in our discussion were those of becoming familiar with equipment, and with standardized tests. These goals have some validity, but I think my final judgment would be that they are suitable as primary goals only for a limited number of samples of equipment and of a relatively few tests which are to be regarded as examples of tests. If a teacher thinks in terms of covering descriptively all the equipment and all the tests that a graduate should know, he gets into two kinds of difficulty; first, there is not time enough to "cover" these items, and secondly, this conception of education is more characteristic of the preparation of the technician than of the professional engineer. We must remember that engineering is changing rapidly; "know how" rapidly obsolesces; it is pressing to help the student to understand so thoroughly that he can devise new kinds of tests (Some of which later may be adopted as standards). He must learn to devise a new engineering art, rather than merely to repeat the old.

After much thought and discussion, the group I speak of decided to recommend these objectives for the laboratory: to help the student

1) learn to think of engineering concepts in terms of physical operations

2) understand the extent of agreement between theory and experiment and the effect of the simplifying assumptions that are inevitably made
3) learn to plan and execute experiments--this means choosing objectives for themselves, devising their own methods, carrying them out in orderly form with appropriate records, learning how to check results and decide whether more data is needed, and presenting information in a clear, concise, and interesting manner
4) become familiar with a few pieces of standard laboratory equipment and learn a few classical techniques. The choices here are important but not all-important.
5) learn to share responsibility and cooperate with his peers in effective teamwork.

Having settled on our objectives, our group of teachers could make real progress in improving our laboratory work. For example, we agreed that there should be some experiments on machine and tube characteristics but that they need be taken only one machine and one tube rather than several of each. In the light of our objectives finding the characteristics of several tubes after the first one adds little to the student's education, and moreover, a great number of points on each of many curves of a family is not really warranted--perhaps a total of only a few points should be taken. Another implication of our objectives was that instructions should be minimized; still another was to let the student decide for himself how to accomplish the test and, as early in this program as possible, even what kind of experiment should be carried out. What amount of instructions constitute a minimum, and how new a situation may be without completely baffling the student and thus being educationally ineffective depends of course on student level, and the previous educational experience he has had. These are a matter of the teacher's judgment and are a test of his skill. Incidentally, I am sure that we often underrate the capacity of a student and fail to make him stretch his mental powers sufficiently, and thereby cheat him of some of the education he has paid form.

I have described this brief study of laboratory objectives not in order to talk about laboratories for their own sake, but rather to illustrate the role of objectives in improving professional education. You may not agree with me on the choice of these particular objectives at all, and up to a point that is undoubtedly desirable, for there is no merit and probably a great loss if the teaching in our many institutions were to be identically the same. But I do want to make the point that if we are to improve our work in education we have to have a clear notion of what we are trying to do. In this case it was laboratory work, and we sought objectives for improving the laboratory. But the use of objectives applies whether we are thinking of day-to-day recitations and homework, any particular problem or report or examination, or the course as a whole, or even the entire curriculum. If we know clearly what our goals are, then we teachers are limited only by our own ingenuity and power in achieving them.

As a matter of fact I have some misgivings about the particular objectives that our group chose for the laboratory, in that the five that were listed may cover too much territory. These had been narrowed down by our group from perhaps a dozen or so but they may not have been narrowed down far enough. Having too many, or too broad goals, is as bad as not having any--it is possible to have so many that one is unable to accomplish even one of them decently. It is like the cowboy that swung up into his saddle and tried to gallop off madly in all four directions!

Thus the art of choosing and using objectives effectively is one of making choices that narrow the scope of the work so that a teacher can do a really good job and one that will be distinctive.

Let us turn now from the laboratory and think about an entire course and the kind of objectives it might have. If we need to be more specific, let me consider a course in electric machines, or in electromagnetic field theory or in electric circuits, all of which I have taught.

If we think about this only casually we might say the objective should be good education. But this, of course, is not very useful if we want the objective to tell us how to plan classes, problems, examinations and so on because the real question, "What does 'good' mean?" has not been answered. We might make another beginning by choosing as our objectives the imparting of factual material. This would be a relatively easy objective to adopt yet even this statement is not very helpful for there is much factual material in any field, more than we can use, and what we require is a more precise statement of objective that can be used as a basis for choosing the particular factual material we will impart. Of course, I also think that the imparting of facts is hardly a worthwhile main objective in professional education.

Another objective we might profess--and I have heard many teachers mention this one--is "to teach the students to think." But again this is too general to be really useful. There are lots of ways that a student can think and lots of things that he can think about--such as what he is going to do when class is over. More to the point, "Teaching students to think" might mean a range of such things as these:

1) understanding what a concept or formula means
2) understanding how the teacher derives a formula
3) being able to derive a formula independently, when he has never seen this done before, or to say nearly the same thing in a different way, to solve an engineering problem that is new to him.
4) to discover new knowledge for himself either by his own work in a laboratory, at his desk, or by using the library.
5) to invent new devices.

These are a few of the many ways in which a student may think and there is quite a difference among them. Thus to say that one seeks to teach the student to think is just as vague and useless in a practical sense and as a working objective as to say that one believes in "good" education without defining what "good" means. These five examples appear to be at different levels but this is not necessarily so and is not what I meant to illustrate. In fact each of these kinds of thinking can be done at quite a low level; an example of the third case, a new problem, might be that of finding the maximum load current that can be drawn from a particular slide wire resistor when it is used as a voltage divider (it is new if the student has not thought about this before) and this involves only electric circuits at the Ohm's law level. Or the "invent" problem might be the one of devising how to interlock two particular switches so that only one can be closed at a time--using either mechanical or electrical interconnections. This and other good examples were discussed in the report of the ASEE Task Group on Engineering Analysis and Design which was a part of the Follow-Up Committee on Evaluation of Engineering Education.

I am sure that if we are choosing objectives for an engineering course we will choose some of the examples of thinking that I have given. I, myself, would give main emphasis to the objectives of helping the student to learn to solve problems which are new to him and of helping him learn how to extend his knowledge.

Perhaps you would agree with my choice, perhaps not. But let us see how the ones I have chosen might be used in planning a course. There is a principle in educational psychology that a person learns from what he does. One of my psychologist friends puts it in a somewhat expanded form, "A student learns from what he does, from all that he does, and only from what he does." If he attends lectures faithfully, he learns to take notes and to assimilate someone else's thinking. If his assigned work is reading and accepting what he reads, then he learns to read and accept. If it is substituting numbers and plotting curves, that is what he learns. If his laboratory work is in terms of complete instructions, then he learns to follow instructions. I have also heard that if he is given examinations which put a high premium on cheating then he may even learn to cheat skillfully. Thus, if we want the student to learn to deal with situations that are new to him--and that is one of the objectives I would recommend--we should give him new situations to practice on. If we want him to deal with whole problems instead of fragments of engineering problems, then we should give him whole problems. If we want him to learn the art of learning from his own experience, then we should have him learn from his own experience while he is still in college and under guidance. If we want him to learn to create things, then we should give him tasks in which he has to create things.

The case of one course with which I have had much experience will illustrate the use of objectives. Our main goal, which in turn was part of an institutional goal, was the non-informational one of helping the student learn how to solve problems that were new to him, and to do this with well-ordered, analytical thinking. Therefore, we gave him new problems, one a week, and criticized his methods of thinking when he dealt with them. We had him follow a pattern of (1) defining the problem, (2) planning the attack, (3) executing the plan, (4) checking results carefully, and finally, (5) taking stock of what has been learned. The problems were difficult enough so that this was not a straightforward sequence, 1-2-3-4-5, but rather a back and forth pattern of devising a plan, trying it, perhaps going back to a different plan, or even redefining the problem. I am sure you know much about this kind of analysis. The kind of problem is all-important because this determines what the student has to do in order to solve it--and what he does is what he learns. In order to put emphasis on the first stage of defining we asked the student to state the problem. Incidentally, with experience we learned to give up the use of carefully worded, mimeographed statements that deprived the student of some of his learning and we came to assign the problems orally and conversationally. In order to give emphasis to planning a solution, the problems varied from field to field, week by week. For example, one week we might ask a student to investigate the possibility of measuring the acceleration of an automobile by a scheme consisting of a dc generator coupled to the engine with its output connected to a resistor and capacitor in series. It was proposed to the student that an ammeter in the series circuit would measure the acceleration and he was asked to find out if the idea had merit. (It does provided the circuit is properly proportioned and a suitable meter chosen) The next week the problem might be to consider an electric cable connected to a motor--the installation conforming to certain accepted standards--and find out whether near the motor the cable might get too hot with consequent deterioration of the rubber. (It would because there was an inconsistency in the standards) Another problem might be to invent a means for having the speed torque characteristic of a motor displayed on the screen of a cathode ray oscillograph during tests of the motor. In this kind of teaching we learned to vary the problems so that the student could not take for granted the principle he would use, or even that his solution would necessarily involve much mathematics although this was common. This made the planning step a real and vital one. We learned to seek problems in which the exercise of engineering judgment was required in making simplifications as a part of the planning, and also in reaching decisions. In coaching the students we always went back to fundamental principles of wide applicability and simplicity like Newton's laws, Kirchhoff's laws, the law of conservation of energy; these rather than equations for special cases were the key to solution. With experience we teachers even learned that we could force a student into orderly thinking by choosing problems in which orderly thinking made it easier to get a good result.

Even after the objective of learning to solve new problems is clear, and we have selected the problem method of teaching, there remain some rather difficult questions such as: what are a sufficient number of problems, just how new should they be and so forth? But I think these are of lower order of difficulty for the teacher--the most important question is whether there are to be any new problems at all. It turns out to be easy to discover by use whether they are new enough or difficult enough or too difficult. If the student solves a problem without any difficulty it is too easy, and a waste of his time; on the other hand, if a reasonably good student is completely baffled and stopped, the problem is too difficult; again it is a waste of his time and damaging to his morale.

If the teacher accepts the other objective of helping the student learn how to extend his knowledge he then must devise assignments that cause the student to do this, remembering again that the student learns from what he does. These assignments may be specially designed problems from which the student learns for himself or they may involve taking the initiative in the use of the library; they may even involve the use of the laboratory.

Examinations are closely related to objectives. The examination should do more than differentiate the good from the mediocre and from the bad students--it should honestly reflect the values and the goals of the course. Thus if we have the objectives that I have chosen we should be sure that some examination questions are new problems to be solved, and that some test the student's ability to extend his knowledge. This kind of testing is exciting to the teacher, for it tells him how he is doing. When but one hour is available for an examination, I have found it best to have it comprise only one or at most two problems; with frequent examinations, such as every two weeks, there is an opportunity to use a number of different types of questions.

Let us return now to another objective that I have mentioned before--that of imparting information. This is certainly an objective of every course but it is one that must be carefully considered and controlled. To put main emphasis on information falls short of genuine professional goals; to impart any information at all requires a careful selection from the mountain of material available in order to obtain a few choice nuggets. If you accept with me learning to solve new problems and to extend knowledge as the main goals, and information as a secondary one, we can try to eliminate material that is too specific, too restricted, and of too limited usefulness to meet the main goals. There is left root knowledge that lends itself to extension, fundamental principles that can be used to solve a wide variety of problems, and a very little bit of background information, and this only on a basis of sampling and related to the problems that the student deals with.

One of the objections that I have to the way many textbooks are written is that they usually include too much material. They are published to sell to a variety of teachers, and it is only good sales sense to put in something that will appeal to every taste. But unless the teacher selects only part of the material in terms of his own objectives his course will never have its own distinctive character.

In my own teaching experience I have usually worked with the three objectives that I have been discussing here--learning root knowledge and basic principles with real understanding, learning to solve new problems, learning how to extend knowledge, and in addition two more: learning to communicate with clarity, precision, and interest, and acquiring an understanding of the economic, social, and human aspects of the technical work. I must confess I have made little progress toward this last and my experience would indicate that even the first four are quite a lot to do effectively in one course of the size we have on our campus. Hence, I think perhaps three of these large objectives are enough for any one course although the curriculum as a whole may well undertake more.

It may be of interest to list a few more important objectives for consideration:

(1) Creativity
(2) Motivation
(3) Initiative
(4) Engineering judgment and judgment generally
(5) Accuracy
(6) Cost mindedness and understanding of costs
(7) Sense of values, both technical and general

All of these are important in engineering education yet it may be difficult to do justice to them all.

It is interesting to contrast the objectives in our field with those in business where there is a well-defined main objective--profit making--and a very precise measure of effectiveness--the dollar. On the other hand, we in teaching do not have a precise yardstick and we even have to struggle to see our goals clearly. Thus it is highly probably that teaching will lack character, distinctiveness, and punch unless the teacher gives a lot of thought to what he is doing--or alternatively is especially endowed with a strong instinct for these things.

We have looked at specific objectives that might be chosen and at the role that they play in courses. A broader set serve in a similar way for the engineering college as a whole, helping to determine the curricula as well as the individual courses.

As a part of this opening discussion, it was suggested that I also tell you about the significant contributions of ASEE. Every monthly issue of the Society's Journal of Engineering Education has something of interest to an engineering teacher, but I think that we have made an even more effective contribution through the projects carried on by groups of our members, who have debated important issues in small meetings until definite conclusions were reached. These projects include the comprehensive studies of 1918 by C. R. Mann, and of 1929 by W. E. Wickenden, the Aims and Scope of Engineering Curricula-1940, Engineering Education After the War-1944, Manual of Graduate Study-1945, revised in 1952, Improvement of Engineering Teaching-1952, Evaluation of Engineering Education-1955, Humanistic-Social Research Project-1956, Report on the Engineering Sciences-1958, Facilities and Opportunities for Graduate Study in Engineering-1958, and the important Engineering Faculty Recruitment, Development and Utilization of this year. And there have been others.

Such studies have been significant in the development of engineering education because they have dealt in an organized manner with important questions, and they have led to carefully considered recommendations. They may have suffered because opinions of committees are more conservative than those of individuals, but they have extra validity because they have survived the battle of spirited discussion and criticism by experts. Sometimes, as in the Evaluation Study, controversial matters were referred to all of the educational institutions for comment and such comments had a considerable influence on the final recommendations. These reports have had an important effect on education, but this has been more often indirect than direct since procedures and even standards in our field are established by each individual institution for itself, except for the influence of accreditation. In our system the most rapid progress has been made when recommendations of the project reports were incorporated into accrediting standards.

In retrospect the studies that have been mentioned do not seem to be very radical or daring; in fact, one wonders if they went far enough. Had they been more far reaching, as the Flexner report was for medicine, we might be further ahead today.

The project that has the closest relationship to this Summer Institute is that on the Improvement of Engineering Teaching and this seems so significant for our purpose here that copies of it are being provided for you. I urge you to study it. Also you will receive copies of the Report on Evaluation of Engineering Education, the most recent comprehensive study in our field and one which has had a considerable influence on the present accreditation procedures and standards of the Engineers' Council for Professional Development.

Most of the other ASEE studies, except for the two most recent ones on my list, were reviewed by one of the most eminent engineering educators, Dean Emeritus A. A. Potter of Purdue in a paper that he prepared for the Annual Meeting of the Society last June. Dean Potter participated in many of the studies himself and was president of the society during the year 1924-25. His historical perspective and his perception of the values of these studies is unsurpassed, and so instead of attempting a similar appraisal I have his permission to give you copies of his, which I am sure you will find well worth reading.

In summary let me say that this has been a most interesting assignment for me. I have tried to point to the great importance of objectives for the teacher, the course, and the institution; to indicate some kinds of objectives that might be chosen; and especially, to show you how the objectives could be used in planning and giving a course. Finally, with the help of Dean Potter's excellent paper, I have pointed to important studies that have been made by ASEE, studies that should be of particular interest to a beginning teacher of engineering.

PAST APPRAISALS OF ENGINEERING EDUCATION

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Engineering education has had the benefit of more extended and careful investigation than almost any other field of higher education. This paper is intended to interest teachers and others concerned with engineering education in a study of the reports in engineering and other professional fields.

1. The Mann Report. In 1907 the Society for the Promotion of Engineering Education, now the American Society for Engineering Education, at its Cleveland Meeting, invited the A.S.C.E., A.S.M.E., A.I.E.E. and the American Chemical Society to join with S.P.E.E. in a "Joint Committee" on Engineering Education to examine into all branches of engineering education, including engineering research, graduate professional courses, undergraduate engineering instruction, etc., and to formulate a report or reports upon the scope of engineering education and the degree of cooperation and unity that might be advantageously arranged between the various engineering schools. A year later at the Detroit Meeting of the S.P.E.E. in 1908 a resolution was passed authorizing this "Joint Committee" to secure cooperation from the Carnegie Foundation for the Advancement of Teaching and of the General Education Board in connection with this study.

Ten years later, or in 1918, there appeared a report of a Study of Engineering Education by Charles Riborg Mann, Professor of Physics at the University of Chicago, under a grant from the Carnegie Foundation for the Advancement of Teaching. This study arose out of the action of the above-mentioned "Joint Committee" on engineering education, representing the principal national engineering societies of this country.

In this report Dr. Mann recommended that in engineering education special attention be given to the use of Good English, human values and costs, and that laboratory and industrial training be stressed throughout the undergraduate program. He, a physicist, considers shopwork "an essential element in the equipment of the engineer." He favored the cooperative type of education, particularly for those planning careers in manufacturing and construction. He deplored the fact that 60% of the entering students failed to graduate, and felt that admission procedures as well as orientation of the entering student should be improved. Dr. Mann questioned the practice under which the fundamental sciences are taught in advance of their applications, and recommended that theory and practice be taught simultaneously. He questioned the performance in mathematics, science, and other fundamental courses as sound criteria for judging the ability of the student to do successful engineering work, and felt that many students are discouraged from preparing for engineering as a career without having any fair test as to their capacity for engineering practice or study. He recommended that in all engineering curricula provision be made for "orientation" contact with real engineering projects during the first two years, including orientation lectures to freshmen, surveying to parallel the study of trigonometry, shop work and other practical courses that appeal to the student's professional ambition and which can prove a help to him in mastering the fundamental subjects. Dr. Mann devoted a whole chapter to "Teachers", and felt that research, as at present treated, does interfere seriously with teaching. He stated that research intended to improve teaching should be given by university authorities equal recognition as creative work in the natural sciences.

Dr. Mann's report unfortunately came off the press at a time when our country was occupied with the First World War and the world was too disturbed to give it the attention it deserved. The Mann Report should be required reading for any person interested in engineering education.

2. 1910-1920 Survey of Land-Grant College Education. This survey, which was delayed in publication until 1925, devotes some space in Part I and II and all of Part IV to education in Engineering and Mechanic Arts. In Part I a chapter is devoted to Educational Values. The first chapter of Part VI recored the following:

> "Engineering Enrollment at 42 land-grant institutions has increased 65.1% during the 1910 to 1920 decade as compared with 75.5% for noncollegiate engineering students and with an increase in teachers of only 47.5%. Engineering curricula of 1920, as compared with those of 1910, stress more uniform entrance requirements, greater attention to English, elimination of a required foreign language, more attention in undergraduate curricula to economics and business, new courses in highways, automation, heat treatment of steel, radio and

> industrial engineering. There is also a trend toward less specialization, more electives, improved shop practice courses, more attention to freshman counselling, and the use of objective tests, greater interest in programs leading to advanced engineering degrees, extension of the cooperative program of engineering education, and greater demand for engineering graduates by industry."

This report has also chapters with considerable historical material by leaders in civil, electrical, mechanical, chemical, mining, architectural, highway, hydraulic and sanitary, ceramic and textile engineering. The last chapter on Engineering Experiment Stations reports a creditable record in engineering research.

3. Report of the Investigation of Engineering Education, 1923-1929 in two volumes, accompanied by a supplemental report on Technical Institutes. Without question this is the most comprehensive appraisal ever published of any field in higher education, with the possible exception of the Flexner Report on Medical Education in 1910. This investigation was also unique in that the engineering schools of this country, as well as the engineering societies, actively participated in supplying the needed data in connection with the extended fact-finding features of this study. This investigation was most fortunate in having W. E. Wickenden and H. P. Hammond as its directors, who visited personally most of the engineering schools in this country, thus gaining an intimate knowledge of conditions essential to an evaluation and interpretation of the data collected. Two trips were made by Dr. Wickenden to Europe which gave him a perspective comparison of engineering education at home and abroad. Without waiting for the final report, Drs. Hammond and Wickenden made available the findings through monthly reports of progress published in the JOURNAL OF ENGINEERING EDUCATION and in numerous pamphlet reports. The initial funds for this investigation were provided by the Carnegie Corporation, and these were supplemented by contributions from engineering societies, industries, universities, and individuals. In addition to the Board of Investigation and Coordination, made up of the top leaders in engineering education, there were special committees of the Society and Faculty Committees at practically every recognized engineering college in North America.

The two volumes of the final report, published in 1930, included 1,320 pages of outstanding information about engineering education and 283 pages on the results of a Study of Technical Institutes.

The preliminary report, released in November, 1926, covered the structure of undergraduate engineering curricula, their social and economic content, admission practices, the problems of the nongraduating student and of the exceptionally gifted student and teaching personnel. The second formal report, presented in June, 1927, covered the relative merits of the unified versus a divided curriculum, the practicability of extending the length of the undergraduate curriculum and postgraduate study. The third report, presented in June, 1929, covered detailed analysis of engineering curricula structure. Separate bulletins were released as soon as completed on the Engineering Student at the Time of Entrance to College, and included guidance of high school students in choosing engineering as a career, admission policies, orientation and guidance of students after admission, a study of engineering graduate and nongraduate students, guidance of graduate in choosing a field of work and in continuing his education after leaving college, teaching personnel, supplementary activities of engineering colleges, costs of engineering education, a study of engineering curricula and degrees, a group study of engineering graduates, the influence exerted by the engineering societies on engineering education, the cooperative system of engineering education, comparative analysis of engineering education in Europe and in the U. S. A., and an analysis of the American Scene. An important outcome of this investigation has been the establishment in 1927 by the Society of Summer Schools for engineering teachers. Those on Mechanics in 1927, Physics and Electrical Engineering in 1928, Mechanical Engineering in 1929, Civil Engineering, Engineering Drawing and Descriptive Geometry in 1930, Mathematics in 1931, English in 1932, and Mining and Metallurgy in 1933 were most significant in improving engineering education.

The two volumes of this survey should be studied by every person who is teaching or is interested in engineering education. Many of the findings by Wickenden-Hammond apply to present conditions in engineering colleges. There are many who feel that this investigation of engineering education and the report by Wickenden and Hammond contributed largely to the fine attitude of industry and of the engineering profession toward engineering education, and that this report may have also contributed to the formation of the Engineers' Council for Professional Development. The Wickenden-Hammond Report was much more extensive than the Mann Report.

4. Survey of Land-Grant Colleges and Universities. A publication in two volumes, published by the United States Department of Interior Office of Education as Bulletin (1930) No. 9. Part I, Volume I reports the status of engineering education at the land-grant institutions, and includes discussions of engineering education as related to the work of the engineer, the standing of engineering at land-grant institutions, student problems, curricula, staff, research, and financial support. The most valuable part of this report is Chapter VI, devoted to an appraisal of the services of the engineering divisions of the Land-grant institutions through the careers of their graduates and teachers, research of value to the States and Nation, and special services to the Federal Government, State Agencies, Municipalities, and public institutions.

5. Present Status and Trends of Engineering Education in the United States. A report prepared by Dugald C. Jackson, at the request of the Engineers' Council for Professional Development and with the support of the Carnegie Foundation for the Advancement of Teaching.

This report, which was published in 1940, involved a survey of 679 curricula inspected by E.C.P.D. in 136 institutions from the Fall of 1935 through October, 1938, and gives a good picture of the status of engineering education in this country in 1939. It also is a critical appraisal of three surveys made of engineering education, and of E.C.P.D. as an accrediting agency. Dr. Jackson concludes that the data and comments made available through E.C.P.D. "abundantly reaffirms the soundness of the central structure of engineering education as it has evolved." This report by Dugald C. Jackson and an Index and Summary compiled by A. P. Johnson may be secured from E.C.P.D.

6. Aims and Scope of Engineering Curricula. A short and realistic report prepared by a committee of S.P.E.E. under the able chairmanship of the late H. P. Hammond and published in the JOURNAL OF ENGINEERING EDUCATION, Volume 30, No. 7, March, 1940. The following conclusions in this report are pertinent and timely:

> "Engineering colleges serve diverse functions and prepare men for a wide range of technical, administrative, and executive responsibilities. Technological education should, therefore, be kept widely available, and engineering colleges must continue to serve a correspondingly

wide variety of purposes. They should not limit their aim to preparing young men for professional registration and practice.

"The present flexible arrangement of four-year undergraduate curricula followed by postgraduate work will better meet the needs served by engineering education than will longer undergraduate curricula of uniformly prescribed duration.

"Engineering colleges could operate more effectively if briefer and more directly practical forms of technological education were provided by other types of institutions.

"Advanced training for the higher technical levels of engineering should be included in the general program of engineering education but should not become its dominating aim.

"Undergraduate curricula should be made broader and more fundamental through increased emphasis on basic sciences and humanistic and social studies. This will require greater efficiency in the use of the student's time to be gained by pruning to the essentials of a sound educational program.

"Some of the advanced technical subject matter now included in undergraduate curricula should be transferred to the postgraduate period where it may be pursued with a rigor consistent with preparation for engineering specialization.

"There are advantages in the parallel development of the scientific-technological and the humanistic-social sequences of engineering curricula. The present integrated type of program extending throughout the entire undergraduate period should therefore be preserved.

"No measures taken with respect to engineering education should limit the freedom that now exists for experimentation and change."

7. Engineering Education after the War. This is another excellent report of a S.P.E.E. Committee, under the Chairmanship of H. P. Hammond, published in the JOURNAL OF ENGINEERING EDUCATION in 1944. It reaffirms and enlarges on the purposes of engineering education as recommended in the Report of 1940 on the Aims and Scope of Engineering Curricula, under two major divisions, the scientific-technological and the humanistic-social. It calls attention to the importance of having more students pursue graduate study in engineering education, as well as to the value of the technical institute type of education. A whole section is devoted to matters of "Immediate Concern", which calls attention to the fact that the present secondary school program is generally inadequate as a preparation for collegiate engineering education, the place of the Junior College, Scholastic Ability vs. Financial Resources, the place of Intensive Programs in Technical Education, the Accelerated Program as undesirable except in special cases or at times of national emergency, and other pertinent problems as a result of World War II, stressing in the conclusion that problems in engineering education "should be considered on broad lines in the interest not only of industry and the engineering profession but of the nation as a whole."

8. A Manual on Graduate Study in Engineering. This committee report with L. E. Grinter as Chairman was printed in the JOURNAL OF ENGINEERING EDUCATION in June, 1945, and a revised Manual was issued in 1952. These represent more than three years of study by the Committee, leaning heavily upon the 1935 Survey of Graduate Work in Engineering, made by the U. S. Office of Education (Bulletin 1936, No. 8, U. S. Department of Interior Office of Education.) This report discusses objectives, organization, graduate faculty, admission requirements, degree requirements, major, minor, and research, the thesis, language requirements and related matters that must be considered in developing graduate programs in engineering. In the last portion of this report the following statement appears, which applies to conditions today even more so than 15 years ago, is worthy of special attention:

> "To gain perspective we must recognize the changing character of graduate study in engineering. Undergraduate curricula in engineering of fifty years ago were heavily weighted with the natural sciences and with liberal subjects. There was not a sufficient body of specialized engineering knowledge or a sufficiently extensive literature to

crowd a four-year program. Graduate study in engineering was not critically needed and could hardly have been differentiated from graduate study in the physical sciences except as it might have contributed a broad review of the engineering arts. Now, this has all changed. New branches of science are developing at an amazing pace within the confines of engineering. Fluid flow, heat transfer, electronics, supersonic aerodynamics, mechanics of stress and of vibrations--these are no longer physics even when physics is broadly defined. Neither can they be defined completely as applications of physics though they use the great body of knowledge that the physicist has accumulated.

"Within engineering itself we see research workers steadily developing these new branches of engineering science. This changing character of engineering, this development from a construction art to a broad productive activity encompassing research, design, and construction, and sustaining within itself the beneficent growth of whole new branches of science, is the vital force of graduate study.

"The assurance which we feel that the scientific or research side of engineering will continue its growth at an accelerated rate is strong support for the belief that graduate study in engineering is destined to grow in importance. Faced with increasingly complex engineering problems that can only be solved with these new scientific tools, industry is turning at an ever increasing rate to the graduate schools of engineering for her future leaders in research, design, and development. That many of these scientific leaders will become administrators we know by observation, and intuitively we feel that specialized graduate study will still contribute much to their ultimate capacities to appraise, digest, and weigh evidence bearing on broader subjects."

9. Higher Education for American Democracy. This report was prepared by the President's Commission on Higher Education and printed by the Government in five volumes in December, 1947. While this report deals only indirectly with engineering and other professional education, the findings and conclusions are of special value to those concerned with higher education. Among the matters discussed in this five-volume report, the following are significant: Education for All, Education for Free Men, Education Adjusted to Needs, the Social Role of Higher Education, Scholarships and Fellowships, Adult Education, Equality of Opportunity, the Economic Barrier, Discrimination in Higher Education, Organizing Higher Education, Staffing Higher Education and Financing Higher Education.

10. Report on Evaluation of Engineering Education. This report was printed by the American Society for Engineering Education on June 15, 1955, and represents nearly three years of study by a committee of the Society, under the Chairmanship of L. E. Grinter. The Committee considers that scientifically oriented engineering curricula are essential if engineering education is to develop people of imagination and competence, and recommended the following means for carrying out this objective:

"1. A strengthening of work in the basic sciences, including mathematics, chemistry, and physics.

"2. The identification and inclusion of six engineering sciences, taught with full use of the basic sciences, as a common core of engineering curricula, although not necessarily composed of common courses.

"3. An integrated study of engineering analysis, design, and engineering systems for professional background, planned and carried out to stimulate creative and imaginative thinking, and making full use of the basic and engineering sciences.

"4. The inclusion of elective subjects to develop the special talents of individual students, to serve the varied needs of society, and to provide flexibility of opportunity for gifted students.

"5. A continuing, concentrated effort to strengthen and integrate work in the humanistic and social sciences into engineering programs.

"6. An insistence upon the development of a high level of performance in the oral, written, and graphical communication of ideas.

"7. The encouragement of experiments in all areas of engineering education.

"8. The strengthening of graduate programs necessary to supply the needs of the profession, conducted in those institutions that can:

   a. provide a specially qualified faculty,
   b. attract students of superior ability, and
   c. furnish adequate financial and administrative support.

"9. Positive steps to insure the maintenance of faculties with the intellectual capacity as well as the professional and scholarly attainments necessary to implement the preceding recommendations. These steps include:

   a. well-established recruitment, development, and evaluation procedures,
   b. favorable intellectual atmosphere, reasonable teaching loads, and adequate physical facilities, and
   c. salary scales based on the recognition that the required superior faculty can be secured only by competitive remuneration, since professional practice in industry and government is inherently attractive to the best minds in engineering.

"10. The consideration of these recommendations at this time before the problems of educating greatly increased numbers of engineers become critical."

11. General Education in Engineering. This is a report of a Committee on Humanistic-Social Research Project, published by the American Society for Engineering Education in 1956 under the Chairmanship of Edwin S. Burdell. Considering the importance of general education for the engineer as a citizen and as a member of a great profession, engineering colleges seem to have neglected to carry out even the minimum recommendations in the Hammond reports for a "designed sequence of courses extending throughout the four undergraduate years." Accordingly, in the interest of their students engineering faculties should give special attention to the recommendations

in the Burdell and Hammond reports, and insist that all engineering curricula devote more than the minimum of 20% of the student's educational time to humanities and social sciences.

12. Engineering, Science, and Management War Training. This is a report by the U. S. Office of Education (Federal Security Agency), published by the Government in 1946. It reports on a successful cooperative project of the Engineering Colleges with the Government of our country, which resulted in preparing through intensive college-level courses more than 1½ million men and women for service to industry during the period of October 9, 1940 to June 30, 1945. This program was most helpful in meeting the shortage of engineers, mathematicians, scientists, and technicians for the U. S. A. war effort. In addition to this, the program demonstrated to industry the value of Quality Control by Statistical Methods, gave an impetus to instruction in ultra-high frequency techniques, provided a stimulus to graduate and advanced programs in mathematics of value to industry, demonstrated the value of technical institute type of education, and brought about a better appreciation of engineering education on the part of the Government and industry.

13. Report on Science and Public Policy. This report by John R. Steelman, Assistant to the President of the U. S. A. and Chairman of the President's Scientific Research Board, was published by the Government in 1947 in five volumes. Volume One is entitled: "A Program for the Nation" and sketches the country's position in scientific research and development, and makes recommendations as to what the Federal Government can do to utilize science for the benefit of the Nation. Volume Two is entitled: "The Federal Research Program" and reviews the Government's scientific work on an agency basis. Volume Three deals with "Administration for Research" and recommends changes so that best results may be obtained from Federal expenditures for research and development. Volume Four is devoted to the problem of "Manpower for Research." Volume Five discusses "The Nation's Medical Research" and points out ways in which the Federal Government can most effectively promote and encourage the extension of scientific knowledge of medical problems.

This so-called Steelman Report, while not directly related to engineering education, represents an outstanding appraisal of the potentialities of science in the Nation's interest. This report and "Science the Endless Frontier," a report by Vannevar Bush to the President of the U. S. A. on a program for postwar research, were without question major factors that resulted in the creation by the Congress of the National Science Foundation in 1950.

14. Medical Education in the United States and Canada. This is the so-called Flexner Report, the most outstanding survey of professional education ever made anywhere in the world; its effects have been most significant in improving medical education and practice in the U. S. A. and Canada. It was issued in 1910 by the Carnegie Foundation for the Advancement of Teaching as its Bulletin No. 4, 1910. Dr. Abraham Flexner found when he started his study that commercial medical schools were firmly established, with an overproduction of uneducated and ill-trained medical practitioners. This was defended by the argument that a poor medical school is needed in the interest of the poor boy--an argument in favor of inferior medical education. Methods of instruction were mainly didactic and with no good clinical facilities. Half of the U. S. Medical Schools had incomes of less than $10,000 per year. While engineering education needs no revolutionary changes of the type found necessary in medical education fifty years ago, the findings and conclusions of Dr. Flexner will prove of value to anyone interested in professional education.

15. Supplementary References. In addition to the above surveys, those interested in education for the professions will benefit by reading "Education for Professional Responsibility", a report published by the Carnegie Press of the Carnegie Institute of Technology in 1948. This report covered the Proceedings of the Inter-Professions Conference at Buck Hill Falls, Pennsylvania, on April 12, 13, and 14, 1948. At this Conference after experiences and ideas of teachers in schools of divinity, medicine, law, engineering, and business were discussed, those in attendance realized that the major problems of professional educations are common to all professions. One hundred representatives were in attendance.

Since the key person in any educational enterprise is the teacher, members of A.S.E.E. will benefit by reading a report on "The Preparation of the College Teacher." This was published by the American Council on Education as a result of a conference held in Chicago, Illinois on December 8 to 10, 1949, and sponsored by the American Council on Education and the U. S. Office of Education.

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PRINCIPLES OF LEARNING

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INTRODUCTION

Education is the system man has devised for transmitting and perpetuating accumulated knowledge in successive generations of young people. Not only does this system convey the knowledge of previous and present ages, but it also attempts to make possible the continued development of new knowledge by these same young people. Man wants simply to perpetuate his culture, but strives constantly to improve it, and he hopes that education of the young will aid in bringing about such improvement. It may be said, then, that education has two broad aims: (a) the transmission of existing knowledge; and (b) the establishing of capabilities in men for inventing new knowledge. Each of these aims can be further subdivided into more specific goals. But it is important to keep both of them in mind in considering the question of the relation of psychology to education.

These materials are designed to provide you with some of the fundamental facts about human behavior and its principles. They are not about all aspects of behavior, but only about the kinds of human activities which are most relevant to the process of education, with engineering education as a particular point of reference. They are intended to give you the fundamental concepts you need to formulate an answer to the question, "What kinds of principles of psychology are applicable to education?"

Educational Goals and Learning.

The attainment of the educational goals we have described is a reasonable possibility because men can learn. That is to say, their behavior can be modified so as to acquire and retain the knowledge that must be transmitted. Furthermore, some kinds of knowledge can be acquired which perform the more specialized function of making possible the invention of new ideas, techniques, and discoveries.

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This modification of behavior, called learning, is the basic characteristic of man upon which education is founded. While it is true that certain capabilities of the very young depend for their appearance on a process of physical growth, the transmission of knowledge from one generation to the next can be accomplished only because of the existence of this capability that man has for learning and retaining. In other words, man does not acquire knowledge because he grows older and physically more mature. He does not acquire knowledge because it "blossoms" within himself at certain ages. Nor does he acquire knowledge simply by living and associating with other people. He acquires knowledge because he learns, which means that some aspect of his nervous system is functionally modified. Moreover, the kind of modification we are speaking of here is retained (or stored): it persists not only for a few minutes, but for months and years, or even throughout the individual's lifetime.

It is apparent, therefore, that the system that we call education can exist only on the assumption of this very important human characteristic (or pair of characteristics) called learning and retention. One can have textbooks, classrooms, teachers, visual aids, boards of education, or whatever may be necessary to establish a framework for education. But the central part of education as a system must remain the man, or more specifically, the human learner. No system of education will be effective if the human learner is not accorded this central role. In this general sense, it is easy enough to understand what makes an effective system of education: it is that system which can most efficiently bring about the learning and retention of knowledge in the younger generation of students.

Differences in Learning Abilities.

All of us know that there are obvious and striking differences between different people with respect to the efficiency they display in learning and retaining. Psychologists discovered many years ago three important things about these observed differences in people. These were as follows:

1. These differences are relatively dependable; they fluctuate because of certain temporary conditions, but not very much.
2. They are relatively stable over the individual's lifetime; they cannot be changed very much by specific training or coaching.
3. They are fairly general, and tend to affect the individual's learning performance on a wide variety of specific learning tasks.

These general, stable capabilities of man in learning and retaining are in fact inferred from controlled observations of his learning of a number of different kinds of tasks. They are usually called human abilities. Intelligence is probably the best known, as well as the most general of these abilities, but there are many others besides. Whatever intelligence turns out to be in actuality, it started out to be an inferred general ability of learning and retaining, and there still remains this aim for the various attempts which have been made to measure it. Disagreements about what intelligence is can usually be reduced to questions about its generality, that is, to how many different kinds of learning situations will it apply? But there is little if any disagreement about the reality of such an ability. No one doubts that people really do differ, in a more or less stable and dependable way, with respect to their efficiency of learning and retaining. The differences between a moron and a successful college student, so far as learning ability is concerned, are as spectacular as the differences between a bicycle and a racing car. And even among such a highly selected group as college students, the differences in ability between a good one and a poor one often continue to amaze the most experienced college professor.

The general implications of the existence of individual ability differences for education are fairly clear. The rates with which people acquire and retain new knowledge differ markedly. This means that when one requires a particular rate for the learning of knowledge, one is automatically setting a pace which will cause some people to fall behind and drop out. If this rate is very swift, a lot of people will fall by the wayside; if it is fairly slow, a much smaller proportion will.

Every teacher faces the problem of establishing a rate for the introduction of new material that is not too fast nor too slow, depending on how many students he wants to leave behind. Usually, this number, whatever it turns out to be, is not too great. This leaves the teacher with the even more difficult and challenging problem of how to adjust the rate so that the fast learners will not simply lose interest in the game of learning. Certainly some methods of handling this problem have been shown to be more successful than others. We shall have more to say about this problem later.

Assessment of Learning Effectiveness.

We have said that learning and the retention of learning are the central human functions with which education must concern itself. If this is so, then the most important question which can be asked about any educational event is, "Has the learning been effective?" One must be concerned, in other words, with the assessment (or measurement) of learning effectiveness. It is not sufficient for anyone concerned with education to say "I have established the framework and conditions favorable to learning." He must be willing to face squarely the question "How effectively has learning taken place?" Of course, this is not always an easy question to answer, and many practical difficulties often interfere with such assessment. Perhaps the most important thing the educator, the teacher, can do is to recognize that this question is always present. It cannot be ignored or argued away. However warmly or coldly he may respond to or be responded to by students, and regardless of the degree of satisfaction or disappointment he may feel, the teacher cannot shun the responsibility of being continually aware of this "pay-off" question, "Has the learning been effective?" It is probably true, also, that the most successful and gratified teachers are those who have found ways of assessing the results of their efforts to induce learning which convince themselves, at least, of the effectiveness of these efforts.

At first glance it might appear that the measurement of learning effectiveness could be accomplished in quite simply ways. Having presented a given amount of knowledge to be learned, one can conceive, for example, of simply measuring how much of this amount can now be repeated by the student. If one wishes to emphasize retention, the same kind of measure can be applied after an interval of time. But there are serious difficulties with this approach. The evidence from many studies of learning shows quite clearly that a measure such as "amount learned" (in the sense of capable of being repeated back) is not at all the same thing as "amount effectively learned." We shall consider some of this evidence later on. But to summarize the major point here, it may be said that a clear distinction can be drawn between "repeatable knowledge" and "usable knowledge." Of course, these are correlated, but they are nevertheless different things. And it is primarily the second kind of knowledge which is a legitimate criterion of effectiveness of educational events or an educational system.

The measurement of usable knowledge is accomplished by observations of transfer of training. This phrase is used to emphasize that what is being assessed is not simply the amount of knowledge which can be "repeated back" in an original learning situation, but rather the amount which can be transferred to a new and different situation. The teacher of high-school algebra, for example, is initially interested in getting his students to find the roots of equations containing variables like x, y, a, b, etc. But he also recognizes the importance of the question of transfer of training: Can these students later use algebra to solve equations containing trigonometric variables like sin x and secant w, as well as the variables of calculus like dx and dt, and the variables of physics like m and a. Thus it comes about that transfer of training, although it may seem a trite phrase because of frequent usage, is really at the heart of the educative process. Assessment of the effectiveness of learning depends upon the measurement of the transfer of initially learned knowledge to some useful human performance. Such performance may, of course, be in the form of an activity which actually accomplishes some social purpose, like building a bridge. Or, it may be a performance which takes place in the context of the learning of new and advanced knowledge.

Human Performance.

Now we have emphasized that learning effectiveness must be assessed, not primarily in terms of the change in behavior which is learning itself, but rather in terms of some human performance. It will therefore be wise, before we turn to a consideration of the principles of learning, to take a somewhat more detailed look at the nature of human performance. If we understand first *what people can do* with their knowledge, we shall be in a better position to appreciate what is accomplished by the process of learning.

Human behavior takes an almost bewildering variety of forms. The first thing we have to note in considering what people can do is that human individuals exhibit a *variety of types of performance*. These types are distinguishable and describable if we put ourselves in the frame of mind of an external observer, and look at the human being with a detached viewpoint, entirely separate from our own private experience. In other words, we must observe the kinds of things that can be used as "inputs" to the human being, called *stimuli*, and the kinds of things that constitute human "outputs", which are often called *responses*. We need to try to answer the question, "What are the different kinds of ways in which human beings transform inputs (stimuli) into outputs (responses)?" In answering this question, we shall in fact be distinguishing the major categories of human performance; we shall be describing what kinds of things human beings can do.

It should perhaps be made clear at the outset that we adopt this mode of viewing man's behavior, not because our readers are engineers, but because this is in fact the viewpoint a psychologist must adopt, if he is to give a scientific account of human behavior. There are certain aspects of the environment which can be manipulated to produce effects on behavior; these are called *stimuli*. When various kinds of manipulations of this sort are carried out, the human being makes *responses*, motor acts on verbal utterances. This is the basic set of observable facts with which the psychologist begins his effort to account for human performance. The basic question is, what kinds of *inferences* can be made about the behavior system? What are the kinds of transformations which are possible from input to output?

The answers to these questions provide us with an account of the types of human functioning, as well as the nature of human performances. At this point in our account, then, we must begin to fill in some details about human behavior. We have introduced the subject by describing some relationships of psychology to education, with particular emphasis on the process of learning. Now we must devote some time to an account of the kinds of things human beings can do, before we go on to see how they learn to do these things.

The Varieties of Human Performance

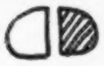
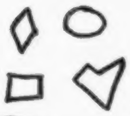
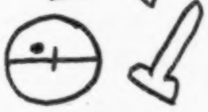
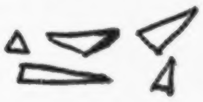
The major concern of the psychologist is to reach an understanding of how the human organism functions as a behavior system. In many ways the approach of the psychologist is opposite to that of the engineer. Unlike the engineer, who starts with a clear-cut notion of the "behavior" he wants to obtain and designs his machine to function accordingly, the psychologist already has the "product" before him--a complex human being, capable of functioning in certain observable ways. Having just described and classified these behaviors, the psychologist is then faced with the even more difficult task of inferring what parts and connections must exist in the human structure, in order that the observed behavior could possibly happen.

The basic parts which constitute the behavior system are sense organs, the connecting nerves, and the muscles and glands which exhibit responses. The fundamental process is one in which a physical stimulus initiates behavior and a response terminates the behavior. While the neural mechanisms underlying this rather automatic transmission are fairly well understood, much less is known concerning the functioning of connections higher in nervous system. We assume that there exist particular mechanisms with certain properties which make possible the various types of behavior.

Accordingly, we must base our account of human functioning on inferences about how various stimuli are transformed into responses. We know that the central nervous system is able to do these things, although as yet no one has traced them out in terms of neural pathways and centers. The kinds of human performance we can distinguish are given in Table 1. Here, the stimulus situation which constitutes the input is given in the first column.

Table 1

Varieties of Human Performance

Stimulus Situation	Type of Performance	Nature of Performance
	Discrimination	"yes" or "no" to difference in physical energy
	Identification	Different responses to different objects
	Motor Sequence	Sequence of motor movements to varying stimuli
3.14159 - - - - -	Verbal Sequence	Sequence of verbal responses
	Concept (Class)	Verbal response which classifies objects on basis of appearance
i before e except after c	Concept Sequence (Rule)	Verbal response or other action which is generalizable to many situations.

A final column provides a brief description of the nature of the transformation which takes place by means of the human nervous system, in other words, it tells the nature of each of these performances. We shall be referring to this table frequently throughout this section.

Discrimination.

Discrimination is one type of behavior performed almost continuously by human beings. By discrimination we mean that the person reacts differentially to stimuli. The individual's behavior indicates that he can "tell the difference" between physical energies. Discrimination is dependent upon the characteristics of receptors, sensory nerves, and their central nervous system connections, i. e., it is a function of the input mechanisms of the system.

Discrimination of stimuli is evidenced when a person's response indicates a difference (or a change) in physical stimulation. For example, discrimination is evidenced when a person can tell the difference (by saying "yes" or "no") between two patches of light of differing intensity placed side by side, or when he states that one note sounds higher than another. The human capabilities for discrimination within each sense modality have been extensively and accurately measured.

In any particular sense modality, human beings can discriminate different aspects of physical stimuli. In the case of vision, a person can discriminate between lights of different intensity; of different wave length; and of different wave composition. Discrimination occurs in all senses; however, the physical differences being discriminated in the case of odors and some other senses are not always well understood.

Not all differences in physical stimuli are discriminated. The study of the smallest differences which can be responded to differentially has received much attention in psychology. These limits of discrimination are an extremely important characteristic, since by determining what energy changes can be reacted to they set the limits of behavior.

It is fairly easy to demonstrate the capacity for discrimination in the adult human organism, by simply instructing him to say "yes" when he sees a difference in physical energy, or "no" when he sees none. But how does the individual first come to connect responses with stimuli? Of course, he has certain built-in reflexes, but these are normally elicited only by particular stimuli, whereas we know the human being can discriminate a great variety of physical differences. How does he first come to make a response to these stimuli? The answer involves the two important properties of the nervous system with which we are primarily concerned: learning and memory. The human individual learns to connect stimuli with responses, and he retains these connections. Thus it comes about that we can use his responses as indicators of physical differences, in the performance called discrimination.

Learning. The human infant, with its limited reportoire of responses, can indicate only a few of the discriminations it is capable of making. The neural connections underlying the discriminations are acquired by a process called learning. Whenever certain feedback effects from the environment are present at the time responses occur, learning takes place. Fundamentally, learning may be considered as the process of acquiring functional neural connections called habits.

Memory. People have the capacity to retain or store as well as learn new habits. Having learned differential responses to red and green, we do not have to relearn them every time we are confronted with those particular stimuli. A neural mechanism called memory enables us to retain these differential habits.

There is an interesting variation here on the analogy between machines and man. The designer of a computing machine determines the "program" which will be given to the machine. In contrast, the human being has a program which is stored by means of memory, and which is determined by learning. The change in what is remembered by a human must be acquired through learning. While most of us do not differentiate between times like 5:05 and 5:06, such habits can be readily formed if necessary. Radio announcers and train dispatchers, for example, learn to make these and finer discriminations. These people do not necessarily have greater discriminatory ability, but their habits are considerably different from those of many other persons.

The learning process thus serves the function of determining the programming of human behavior. Through learning human beings may come to have more or fewer habitual responses to different stimuli. They also may acquire entirely different sets of habits by learning. If it were necessary that automobile drivers come to a stop at green lights and start again when the light turns red, the "memory program" could be changed by process of learning. Again, if future cars replace the accelerator and brake pedals with push buttons, the appropriate new responses could be readily learned.

The human memory, then, is conceived not as a device for the passive storage of facts, but as the retention of patterns of connections between stimuli and responses (habits).

The adult human being has acquired by earlier learning a great variety of functional neural connections. These connections, stored in his simple habit memory, can be drawn upon whenever he has to make a discrimination. Nodding, shaking his head, saying yes or no are a few of the large variety of motor and verbal responses which the human organism can make. Although presumably each of these habits was originally learned in a specific situation, they are well established in the adult, and may easily be transferred from one situation to another. On the other hand, for the human being to use new differential habits which conflict with old ones (such as pushing buttons to shift gears in a car), he must be given a new situation in which he can learn them.

Identification. In making differential responses, it is apparent that the human being is able to do more than simply provide a response which indicates a difference in physical stimulation. He is also able to identify stimulus qualities in terms of a remembered model or scale. This model comes into play when we show a person a light of a particular wave length and ask him to identify its color. The identification may only entail saying whether the light is or is not green, but the process involves a differential response in terms of a remembered standard or model of "green". (The simpler discrimination situation would be one in which two lights of different wave length are presented and the person asked whether they are the same or different).

Whenever we have to make a response on the basis of some absolute category we utilize our memory for scales and models. An identifying response may be said to occur whenever the individual makes a response which identifies a difference (or lack of difference) between a present stimulus and a remembered standard which is not physically present. We all have remembered scales for such common things as length, time and weight; we also possess models such as those of color, straightness, curvilinearity, and roundness.

There exist large differences between individuals with regard to their stored scales and models, depending primarily on what they have learned. We are all familiar with the fact that some people are much better able to judge absolute distances than others. Some are able to identify more colors than others.

Compared with the discrimination we can make, the scales and models we use are quite gross. Thus, we can discriminate when two straight rods about 3 feet long differ from each other by a fraction of an inch; yet few of us can identify lengths in this range to any degree finer than 3 inches. While most of us can make differential responses to about 128 differences in color in progressing the spectrum from the red to violet end, we nevertheless ordinarily make only 6 identifications.

These remembered models and scales can become much more precise through learning. Musical training, for example, produces remembered scales and chords that enable the person to identify patterns which the untrained person cannot. The deaf person may learn a set of models of lip movements which allows him to identify these to an extent that far surpasses the rest of us. The greatest differences are in our scale and model memories, and not in our basic discrimination capacities. Most of us could learn more precise scales if we took the time and were highly motivated.

Motor Sequences

Another important function of the human nervous system is one which comes into play in integrated response-sequences called motor skills. A motor skill is a sequence of habitual responses the order of which is partially or wholly determined by sensory feedback from preceding responses. Walking may be considered as a motor skill, since each succeeding response in the chain is affected by sensory feedback from the immediately preceding response. Thus, upon lifting his left leg a person receives sensory feedback from the muscles of this leg, as well as alterations in pressure on the sole of right foot; in response to this stimulation, the left leg is extended and touches the ground, providing a new pattern of stimulation; the right leg, in response to this different input pattern is drawn back, creating another new pattern of sensory stimuli, and so on. The total skill is a well integrated sequence, in which previous responses provide the necessary stimulus for next response. Motor skills are not simply a matter of differential responses but involve connections which guide an entire sequence of behavior. The fact that one can make the responses of walking even while suspended in air, or go through the motions of tieing a tie without having a tie present, are everyday examples which illustrate that the connections are stored in the memory. This storage by the nervous system makes possible the enactment of habitual response sequences even though the entire stimulus situation is not actually present.

Table 1 illustrates a motor sequence by suggesting the tracking of an irregularly moving target by movements of a control handle. This is a common and useful kind of performance called "tracking". What the table is unable to indicate adequately is that an important source of stimulation derives from the movements of the muscles themselves, via the kinesthetic sense. This kinesthetic input serves as a "feedback loop" in regulating subsequent responses. Thus, if the first response has been in error, the feedback stimulation allows a correction to be applied to the next response. Consequently, a smoothly regulated series of actions constitute the total sequence. While some motor skills are largely controlled by feedback from the muscle sense, others are regulated primarily by external feedback from other senses. The predominant source of feedback is an important property in classifying motor skills.

Verbal Sequences

Sequential performances also occur in verbal form, and these deserve special mention since they constitute an important human function. The recitation of verbal sequences such as the alphabet, the multiplication table, poetry and prose passages, or π to any number of places beyond the decimal point, are examples of verbal sequences, all of which have a formal similarity to nonverbal motor skills. Such verbal sequences are controlled and corrected by stimulus feedback in much the same way as nonverbal skills, although such feedback derives primarily from external stimulation, rather than from the muscle sense.

Obviously, the capacity of human beings to retain such sequences is tremendous, and seldom is used to a full extent by the average person. Some people, it is true, amaze us with the repertoire of retained prose and poetry passages they have memorized. People have been known to memorize whole books, word for word. A convenient property of the verbal-sequence memory is that specific sequences are readily forgotten after relatively short intervals unless particular pains are taken to reestablish them by additional learning. The poetry passage we learn in school fades away in a few days or weeks unless it is relearned. But we do not know exactly how great the limits of the verbal-sequence memory may be. Presumably, any one of us could increase the number of verbal sequences he retains hundreds of times, simply by undertaking the necessary learning.

Fortunately, we do not have to depend on retained verbal sequences for the reinstatement of many kinds of human knowledge, because we have a much more efficient mechanism available to us. We can recall what we read in a textbook, for example, by using concepts, which we shall next describe. Briefly, this mechanism enables us to retain the meaning of what is read in simplified form, and so to reinstate it without repeating it word for word. If a student had to pass examinations by recalling verbal sequences, he would indeed lead a dull life. As it is, he uses his verbal-sequence memory to retain only a relatively few prose passages, formulas, and the like, and depends upon the learning and retention of concepts for the major part of his education.

Using Concepts

We have now considered a person's ability to discriminate, to identify, and to respond sequentially as aspects of human performance. If only these mechanisms were put into a model, we would have something comparable in many respects to an animal. The learning, storing, and using of concepts is a prominently human function. Behavior based upon "abstraction" or "generalization" is made possible by our ability to utilize concepts. Man's behavior can be determined by classes of objects and principles because of his ability to conceptualize.

Man is able far more than other animals to respond appropriately by generalization to various new situations. We may be able to teach the family dog to go to the back door of the house on the command "Back" or the front door on the command "Front". But this habitual response will show very little generalization to other situations, compared with the amount shown by humans who use verbal concepts. Human beings, in effect, say to themselves "front" and "back". We are able to guide our behavior in many different specific situations by using concepts.

To a far greater extent than animals, man is capable of storing these verbal signals over a long period of time. Animals are not able to retain and reinstate commands given to them. In contrast, we could tell a child an hour in advance, "When we arrive home, go to the back door.", and expect an appropriate response at that time. The human being, then, is able to store and reinstate a general class word for extended periods of time.

While animals can learn quite readily a specific path to a goal, as in a maze situation, there is a tremendous difference between this specific skill and the way in which we can direct a person to a goal along an unknown path by giving him verbal instructions. Animals cannot learn a rule to guide them in a new pathway; they are dependent on external stimuli. By his use of language, the human is able to learn the principle involved.

We may define a "concept" as a stored set of connections in which a verbal signal controls the arousal of habits appropriate to new situations, so that the learning of new specific habits is unnecessary. A concept functions to reinstate an entire set of appropriate habits; it enables the person to generalize appropriate responses to a variety of particular situations. Originally, of course, concepts are themselves learned. They are also modified by learning. The operational meaning of a concept is to be found in the set of habits it arouses.

As was the case in motor skills, a stimulus-feedback loop is part of the mechanism pertaining to concepts. The ability of the human to say back to himself specific verbal signals provides the feedback to the concept memory. The unspoken verbal concepts which are aroused serve as signals for appropriate responses.

A particularly important function of concepts is their use by human beings in thinking, or problem-solving. This "internal trial and error", as it is sometimes called, means that the person produces "trial" concepts which express the results of his behavior, and then chooses the concept which will best achieve the desired outcome.

Performances and Learning Requirements

We have now described in some detail the various kinds of human performances which are available to human beings. Our primary reason for doing this is that we believe the teacher must have a firm grasp of what human beings can do, if he is to understand how they learn to do these things. In other words, we believe the first question the teacher should ask, in considering the learning process, is the question of what is to be learned. The conditions to be established for effective learning, as we shall see, depend to an important extent on this question of what performance we wish to establish by means of learning.

Some specific principles which relate types of performances to the requirements of learning are given here. We shall be discussing most of them in greater detail in a subsequent section. The reader may wish to refer back to Table 1 in order to keep in mind the nature of each kind of human performance.

1. Discrimination. Usually, education is not concerned with this kind of performance to any great extent. Although discriminations occur in such activities as reading meters, aligning transits, or using light-measuring instruments, it is usually assumed that students are

capable of these performances, or can be screened out if they are not. But a more important reason is that, according to most evidence, discrimination is not subject to modification by learning. Occasional reports of such things as improving color-blindness by learning usually turn out to be based on the learning of new identifications, rather than the improvement of discrimination as such. Training people to see in the dark, which is perfectly possible to do, is not a matter of modifying discrimination capacity, but rather of teaching new observational habits.

2. Identification. In contrast to discrimination, the learning of identifications is a highly important and pervasive part of education. The engineering student must learn to identify, by name or other response, a great variety of things, tools, and instruments. Furthermore, any new subject that a student meets is bound to have many new identifications to be learned--new names, new symbols, new locations. While identifications should not be confused with concepts (i.e., the meanings of words and symbols) it is nevertheless an important fact that there is a great deal of identifying to be done before concepts can be acquired.

3. Verbal sequences. Some verbal sequences must be memorized. Common squares and square roots, frequently used formulas, and other things of this nature may readily be learned as sequences. While this is surely not the pattern for education as a whole, the memorization of verbal sequences is not difficult to do, and may be a highly useful thing to do. There is some reason to believe that in certain kinds of performance, memorized verbal sequences may play a more important role than is generally realized. For example, it may be that for a performance like speech-making, the availability of well-memorized passages from Shakespeare or the Bible makes a tremendous difference in the successfulness of an extemporaneous performance.

4. Motor sequences. These are involved in a number of practical things the student engineer may be required to learn, including the manipulation of tools and instruments. A subject like drafting is, of course, a kind of performance which requires the learning of a number of specific tool-using skills.

5. Class concepts. Many new class concepts must be learned in any newly introduced subject matter. A student in electrical engineering, for example, must learn to classify all the varieties of things that are resistors, transformers, amplifiers, and so on. Again it may be said that learning class concepts is something that must be done before rules and principles can be adequately acquired.

6. Concept sequences. Perhaps the most important variety of concept sequences to be learned are the rules and principles which make up the structure of any academic subject. These constitute the crowning achievement of the educative process, for it is usually in terms of their mastery that the learning of knowledge is assessed. They must be learned, just as simpler performances are learned. Furthermore, we need to remember that the learning of rules and principles is based upon the prior learning of simpler things, particularly identifications and class concepts.

Implications for Education.

The major implication of this categorization of human performances that we have undertaken is this: Effective conditions of learning are different for different kinds of human performance. While it is true that there are some "general" conditions for learning, as we shall see in the next section, it is of utmost importance to recognize that different kinds of things to be learned take different kinds of learning conditions. One of the teacher's major functions is that of arranging suitable conditions for learning. Since this is so, the teacher must be highly aware of what is to be learned and of the effective conditions which pertain to the learning of different performances. The conditions which facilitate the learning of motor sequences, for example, will not help with the learning of class concepts; and similarly for the other varieties of human performance.

It is now time, therefore, to turn to a consideration of the processes of learning and memory. We shall do this by discussing first the basic nature of learning, and the conditions which do appear to be general in their application to this process. Following this, we shall be concerned to describe the conditions which are specific to the learning of each type of human performance as we have discussed. It will be apparent to the student that there are distinct limitations to our knowledge, particularly of these specific principles. All we can do here is to summarize what is known to the best of our ability. Much is known about learning, as we hope you will see; but a great deal more is unknown. And it will be equally apparent, we trust, that learning is a process which can be studied and understood by scientific means. The unknown aspects of human learning are attributable to the particular stage of development of the science of psychology; not to the fact that they cannot be discovered.

Learning

Human performances are dependent upon the retention of previously acquired habits, motor skills, verbal sequences, models, and concepts. The basic question which is asked now concerns what the process is by which these basic skills develop to the point where they can be utilized in the vast array of tasks people have to perform. This question will be answered in accordance with an emphasis on the conditions that must be present for performance to emerge and be molded. These conditions have an effect on the organism concerned, involving activity in the nervous system. This neural process which underlies the occurrence of a change in performance, when not a result of growth or fatigue, is what we call learning. The conditions that must be present for learning to take place are events partly internal and partly external to the person. At the present time not much is known regarding the role of the nervous system and physiological factors in general in their relation to the learning process. Psychologists have traditionally concerned themselves with the study of the external factors involved in learning and are able to specify these with some degree of assurance.

The Learning of Simple Habits

The acquisition by human beings of simple habits, the fundamental connections which are basic to all learning, is difficult to investigate directly. One reason for the difficulty is the wealth of habits built up in the past that a human adult will bring with him to a new situation. Thus, it is extremely difficult to put an adult into a situation where his past experiences will not in some way affect his performance. In this instance what might be studied would not be simple learning, but perhaps the application of concepts already learned. It is difficult to get at the situation of building up a habit from the ground.

To circumvent these difficulties investigators have utilized children as subjects; dealt with adult reflex responses, and turned to the study of animals. All of these alternatives have met with some success and also possess some limitations.

When using children as subjects novel situations are often readily available. It is possible to study just how the child learns such things as reaching out and grasping his bottle, manipulating toys and puzzles, and making simple identifications such as picking up a box that contains a particular toy that he wants. Here again, however, there are certain dangers that may cloud a clear understanding of the processes involved. As the child grows older his nervous system grows, and it becomes necessary to distinguish what portion of the child's behavior is attributable to his learning a new task and what is attributable to the maturation of the nervous system. Thus, it is essential to use children that are not too young for the particular learning being studied. At the other extreme, if the child is too old for the task being studied the same problems may be encountered as with the adult, namely, the utilization of past learning in the new situation. Choosing the right age for a child then becomes a critical problem.

When working with reflex responses in adults it is possible to attach new signals to old responses and thus develop new habits. One of the reflex responses in the adult human repetoire is the reflex eyelid-blink associated with the presentation of a puff of air on the cornea of the eye. This response has been trained in various experiments to be called forth on the presentation of such stimuli as a brief flash of light or the sound of a bell. As another example, it is possible to have a stimulus such as a light or sound elicit behavior that would normally be manifest when a mild electric shock is delivered to the hand or arm. The behavioral change resulting under this condition can be measured by means of a reflex response known as GSR (galvanic skin reflex), which is a change in the electrical resistance of the skin. The advantage of using such reflex responses as the eye-blink and GSR is that these responses are normally not directly controllable by the use of previously learned concepts. (The involuntary blink of the eye in these studies is not the same as the voluntary blink used in normal "winking".) As a result, we can study the acquisition of habits such as responding to a tone by a change in the electrical resistance of the skin (GSR), under the assumption that there is no conceptual process being invoked by the subject that controls its occurrence. The acquisition of habits which represent the attachment of new signals to reflex responses is what is meant by the development of conditioned reflexes.

The use of animals in the study of simple-habit learning has been extensive, and has proved to be advantageous for many reasons. Chief among these reasons is that an experimenter can control directly the motivation of the animal by determining, for example, the amount of food or water given to the animal. Commonly used animals for these purposes are the white rat and the pigeon, primarily because these organisms can be safely assumed not to be able to form concepts as a human can, nor be able to discern what the purpose of a given experimental situation is. Higher on the phylogenetic scale, the behavior of animals like monkeys and chimpanzees does not permit the assumption of absence of conceptual control. Simple habits can safely be assumed to be acquired by white rats in about the same manner as in human individuals owing to the marked similarity in the nervous systems of these organisms, except where higher order concepts are considered. As long as the extrapolation of behavior is on a simple level there is little danger of misinterpretation of events. It is only when we are dealing with behavior that is controlled in the higher centers that this extrapolation from lower organism to man becomes somewhat tenuous.

The Learning of a Simple Habit

An example of animal learning will be presented to describe the conditions necessary for the aquisition of a simple habit. A white rat is at hand that has had experience in running along narrow pathways and has had the experience of eating food in a box at the end of the path. It is desired that the rat learn the habit of emerging from one box, called the starting box, and running along a pathway to get to another box, the goal box, where he finds some food which he may eat. In this situation the habit to be learned is that of running out of the starting box once the door in front of it is opened. With a constant time between trials of 75 seconds, learning was measured over a number of trials. The individual trial commenced with the opening of the starting-box door ending with the consumption of the food by the animal in the goal box. The measure of learning was the amount of time it took the rat to get to a point four inches in front of the starting box after being released by the opening of the door.

When the rat is initially placed in such a situation his early behavior is quite varied. He moves about exploring all of the walls and floor of the box, he sniffs, engages in scratching his own body and the walls of the box. Eventually he leaves the box and after a time in the runway comes to the goal box and eats the food. On successive trials, lesser amounts of this type of "random" activity are observed. The rat comes to orient himself in relation to the door of the starting box, sitting and waiting for it to be opened. The extraneous behavior drops out and the time it takes to leave the starting box becomes progressively less until there is no longer any measurable improvement in his running speed.

What happens, then, is a lessening of other activities and an increased dependability of the response of orienting himself toward the runway and running out of the starting box. Thus a simple habit has been learned in response to the opening of a door leading to the runway. The language used to describe this change is that the probability of the response of running when the door is opened is increased from almost nothing to a point where the response almost always will occur. It can be further demonstrated that this newly learned behavior is persistent and will occur for a long period of time. Whereas other rats who have not had this experience will produce behavior similar to what this rat first engaged in, the present rat has developed a habit; his activity is highly predictable.

There is much variation from trial to trial for any given animal in this situation, but if a group of animals is used, the variability in average behavior is lessened, showing a fast initial drop in time needed to reach the goal box, then a gradual improvement which levels off after the animals become proficient. Thus, a learning curve is produced that will be applicable in describing the probably behavior of rats in general in learning this response. Other simple habit acquisition curves can be shown to follow this general pattern, as illustrated in Figure 1.

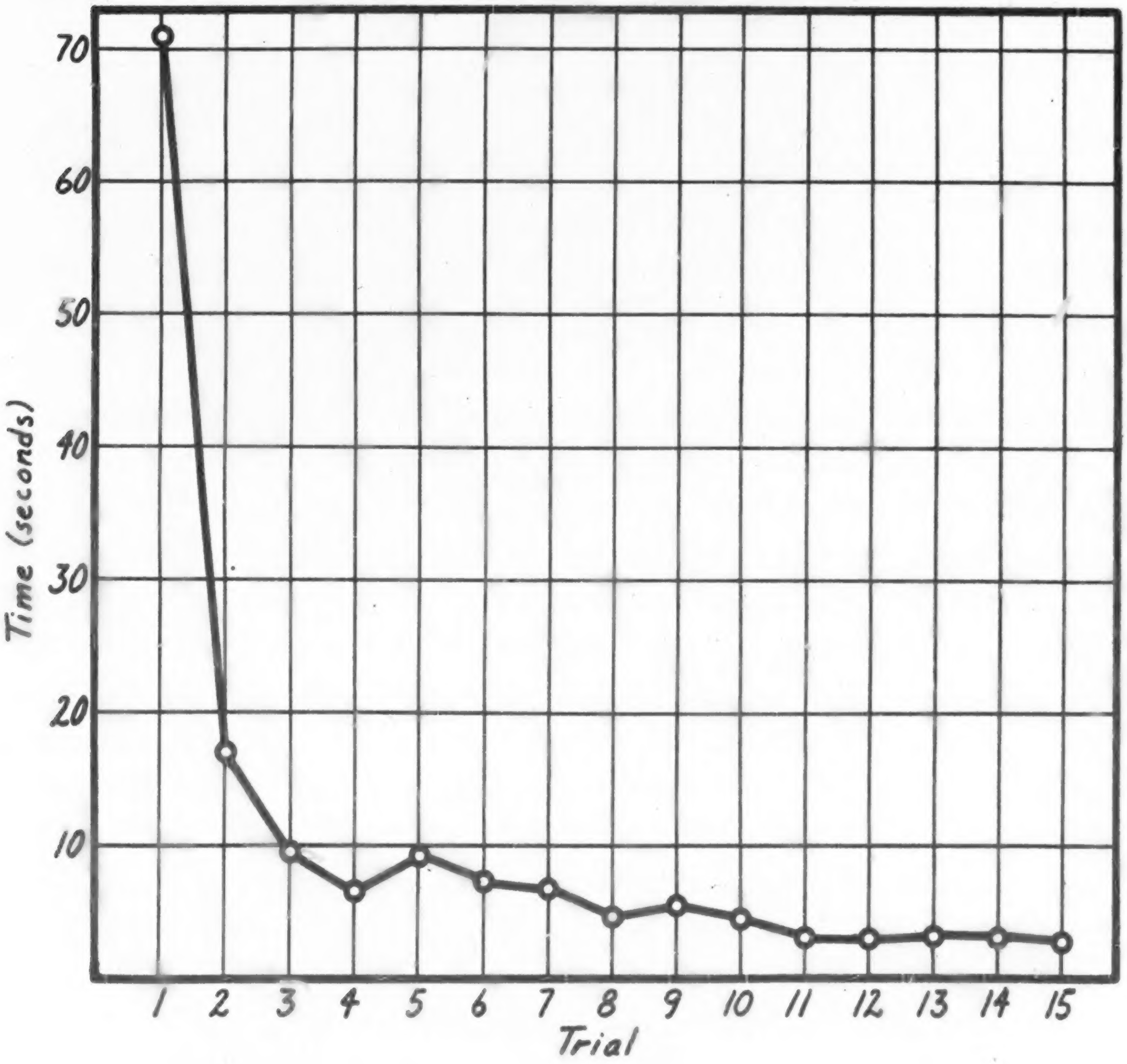


Figure 1. The learning of a simple habit in a group of white rats. The average time taken to leave the starting box is shown for 15 practice trials. (Data from Graham, C. H., and Gagné, R. M., The acquisition, extinction, and spontaneous recovery of a conditioned operant response. J. exp. Psychol., 1940, 26, 251-280).

Similar courses of learning have been measured in human beings, using such simple habits as the conditioned galvanic skin reflex and the conditioned eye blink. It appears reasonable to state that the general form of the learning curve for the acquisition of simple habits is one which is negatively accelerated, showing its most rapid change within the first few trials.

Conditions of Learning

To make clear the conditions of learning a simple habit the situation of the rat running down the runway will be used. The four conditions to be considered are (1) motivation, (2) practice, (3) reinforcement, and (4) freedom from distraction.

Motivation. The experimenter in the above experiment first regulated the intake of food by the rat, so that there was a hungry animal who was motivated to search for and consume food. This condition was necessary for the animal to run the runway to get the food at the other end. If hunger were not motivating the animal he might have sat down in the starting box or even gone to sleep, not concerning himself with exploration and eventually coming to the location where the food was placed. In general, a non-hungry rat would usually be inactive and the probability of his engaging in the running response toward food would have been extremely low.

Other motives might have been used in the experiment. The basic motivations that are commonly employed in experimentation other than hunger are thirst, pain-avoidance behavior, sex, and the drive for exploring the situation. Besides the basic drives the human subject has a wealth of learned motives like the need for approval, which have been acquired as a result of previous learning.

Practice. The behavior that was initiated by the animal being motivated requires the repetition of the situation in a number of trials to become an effective habit. The learning curve described for the animal indicated a sharp initial drop in time to run the runway, followed by smaller decrements as the practice was continued. Some habits are almost fully developed after the second trial and no further learning is noticeable. The rate of acceleration is dependent on the nature of the habit being practiced, sharp slopes being connected with easy tasks and gradual slopes with more difficult tasks.

7

The strength of the habit learned in this runway task is usually measured by the time it takes to perform the task on a given trial, with the greatest habit strength being associated with the shortest response time. Habit strength then is a direct function, along a negatively accelerating curve, of the number of practice trials on the task.

Reinforcement. It will be remembered that after running to the goal box the rat found food and ate. Thus the activity set in motion by the motivation of hunger was culminated in eating behavior. When a signal-response sequence of behavior such as this is followed by a reward (like food) the animal is said to have received reinforcement. The habit that is being learned is reinforced with each trial.

Along with motivation and practice it is necessary that the animal be reinforced, for the habit to develop. Experiments have indicated that regardless of the motivation and the number of trials that an animal is placed in a starting box and made to run a runway learning does not occur unless the food in the goal box is actually consumed. The situation in human learning is not quite so simple as this. But some form of reinforcement, not necessarily a physical reward, is necessary for learning to take place.

Freedom from distraction. If, during the course of learning, a strong generalized response occurs as a result of some emotional disturbance, the acquisition of a simple habit can be interfered with. A loud noise or an electric shock can arouse an emotional reaction in the animal that will interfere with his acquisition of the proper response on that trial and may cause interference on future trials. This factor may be of particular importance when considering the effects of punishment on learning.

Summary of basic learning conditions. When we are dealing with the establishment of simple habits, the fundamental connections which are believed to be the building-blocks of all learning, the following conditions are seen to be important: (1) a motivated individual; (2) reinforcement shortly following the signal-response association to be acquired; (3) practice, or repetition of the association; and (4) freedom from distracting emotional stimulation. With successive practice trials, the strength of an acquired habit increases in a negatively accelerated manner. The slope of the curve, however, depends upon the difficulty of the task which defines the habit to be learned.

Extinction

Once learned, a habit may be subjected to an "unlearning" process called experimental extinction or simply extinction. This weakening of the habit occurs when the reinforcement is removed. In other words, continued repetition without reinforcement leads to a progressive decrease in the strength of a habit until it disappears altogether. For example, following the events shown in Figure 1, extinction of the habit was brought about by continuing to place the animal in the situation but removing all food from the goal box. Within a few trials, the time taken by the animal to leave the starting box was approaching the value it had at the beginning of learning. This phenomenon is not to be confused with forgetting, the weakening of a habit over a relatively long period of time; it appears rather to be an active erasing process. As we shall see, extinction plays an important role in more complex forms of human learning. The reason is that many aspects of new situations have to be unlearned, as well as newly acquired.

Learning Theory and Education.

Most learning theory concerns itself with the inferred internal mechanisms that may be required to explain the occurrence of simple habit learning. Furthermore, the particular point of emphasis of learning theories is the nature of reinforcement. The kinds of questions modern learning theories seek to answer are the following:

1. Is the effect of eating food at the end of the runway (using our previous example) to produce a state of "motive satisfaction" which strengthens the habit? Or, alternatively, does the food simply act as an incentive to increase the speed of running, having no direct effect on what is learned?

2. Is the animal learning an "internal map" of where the food is located, or is he acquiring simply a stronger "response tendency" of running toward the food?

These are important questions, and they are difficult to answer. They have led to the design and execution of an enormous number of experimental studies of both animal and human learning. Such studies will undoubtedly continue, since we have as yet no clearly acceptable answer to the problem of how reinforcement works. It is possible that modern work involving direct stimulation of the brain, and learning phenomena associated with such stimulation, will provide some more definitive answers to these perplexing questions.

The important point to be noted, so far as education is concerned, is that learning theories typically address themselves to these very basic problems of simple habit learning. They are not concerned with the learning of more complex performances like those we described in the previous section. Actually, there would most probably be a high degree of agreement among learning theorists concerning the relevance of certain basic phenomena to these more complex types of learning. The facts of reinforcement, for example, are seldom questioned by learning theorists holding different views concerning learning mechanisms. The phenomenon of extinction is generally considered to be of great importance to an understanding of the learning process. The effects of repetition are not questioned by most modern theories. And the requirements of motivation and freedom from distraction are similarly widely accepted.

When we proceed to an account of more complex forms of learning, we have little theory to guide us. We shall need to make use of the facts of simple learning wherever they are applicable. Beyond this, we must depend upon a great deal of relatively unorganized empirical evidence about human learning. Perhaps the best guide we can use is the classification of human performances outlined in the previous section.

The Learning of Different Kinds of Performances

In this section discussion will center around the acquisition identifications, verbal and motor sequences. Following this, we shall consider conceptual learning and the use of concepts in problem solving.

Identification Learning.

An important and basic kind of performance learned in all varieties of subject matter is identification. As we have seen, this is a matter of learning a number of different responses which serve to distinguish a number of different stimulus objects. In beginning a new subject, one learns the names for a great number of different objects. Sometimes, there are new symbols to be learned. Or again, one may need to learn positions or directions of movement in response to certain instrument readings, as does a student pilot, for example.

Basically, the learning of identifications is a matter of acquiring a number of simple habits, the number corresponding to the number of objects to be identified. It is generally believed that the establishment of each of these habits follows the course of learning described for simple habits in the previous section. Furthermore, it is expected that the general conditions of learning will be applicable in identification learning--namely, the effects of motivation, practice, reinforcement, and freedom from distraction. Reinforcement usually takes the simple form of informing the learner about the correctness or incorrectness of each identification response he makes during learning. An example of a curve showing the progress of a group of subjects in learning a set of names for 13 nonsense figures is given in Figure 2. Five practice trials are shown.

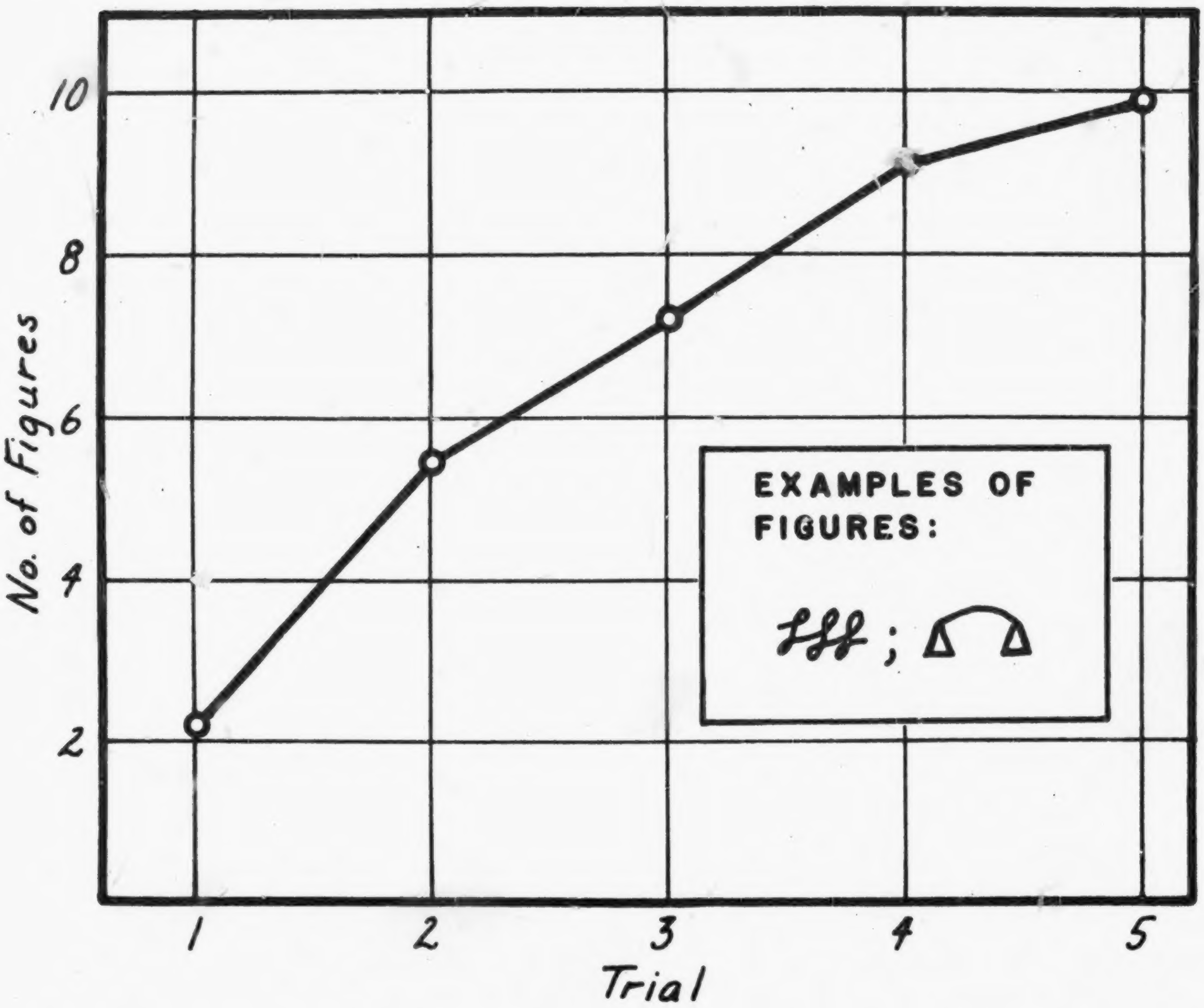


Figure 2. The identification learning of 13 nonsense figures, of which two examples are shown. Correct responses are plotted against trials of practice. (From Gagné, R. M., and Fleishman, E. A., Psychology and human performance, Holt, 1959. Fig. 6. 10, after Gibson, E. J.)

It is apparent from this figure that the learning of a set of identifications like this is not simply a matter of "adding up" the learning of 13 separate simple habits. The primary additional factor at work here is interference. That is to say, at the beginning of this type of learning, there is considerable confusion among the simple habits to be acquired, and the learner tends often to give the wrong name for any given figure. Learning in fact is most importantly a matter of unlearning incorrect habit tendencies, in order that each stimulus object is finally distinguished (by different responses) from every other. Evidence shows that extinction of wrong responses is a prominent feature of identification learning. The mastery of identification tasks is largely a matter of progressive reduction in interference, brought about by "contrast training" which informs the learner of "right" and "wrong" responses.

The difficulty of identification learning, as exhibited by the slope of the learning curve, is affected by two main factors: number of stimuli to be identified, and the similarity of these to each other. As the number of separate identifications increases, the learning becomes slower and slower, presumably because of the increased tendency for interference among the set of habits being learned. The greater initial resemblance these stimulus objects have with each other, the slower will learning progress be, again presumably because of heightened interference.

Motor Sequences

Single habitual connections, either verbal or motor, may be "chained together" in sequences of larger behavioral patterns. Motor sequences of this sort are usually called motor skills. Comparable sequences may, however, be established with verbal responses, as we shall see in the next section.

Following the presentation of an initial stimulus situation, each response in a motor sequence provides a signal for the next response. Succeeding stimuli in the sequence may be based on the effects of the last response, by way of the kinesthetic sense, or from contact in some way with the external environment. The resulting sequence then can be diagrammed as:

$$S_1\text{-}R_1 \longrightarrow S_2\text{-}R_2 \longrightarrow S_3\text{-}R_3 \longrightarrow S_4\text{-}R_4$$

Any individual response in this chain may be a discrete unit; or the response might be a member of a chain of continuous behavior in which the individual response cannot be identified except by an arbitrary classification. When a person draws a triangle on a piece of paper without lifting his pencil each line can be seen as an individual response, whereas when asked to draw a circle, only one continuously flowing movement is discernible. Much of the work that has been concerned with the development of motor skills has been concerned with considering the response chain as a continuous unit and emphasis has been placed on the studying of the task to be performed as a whole rather than studying its elements.

As with the development of simple habits, motor skills require for their development the conditions of motivation, reinforcement, practice, and freedom from distraction. Practice has the effect of improving the performance of a motor task, and usually continuing practice increases performance over a relatively long period. However, much is dependent on the accepted criteria for mastery of a task. For example, if a person is capable of staying afloat in the water and capable of maneuvering in any given direction he may be classified as a swimmer, yet in a swimming competition this person might hardly stand a chance. Improvement may be measured in a number of ways such as accuracy, the number of errors per given number of trials on a task or the number of correct responses within a given time. In general, practice on a motor skill leads to increased speed of performance and increasing accuracy.

In performing a motor task reinforcement is usually supplied by the knowledge of the results of the performance on the task through "feedback". For example, the person learning to type sees the mark on the paper after pressing each key, and can correct his errors in the future. It has been found that more precise feedback can usually increase efficiency of performance. In situations where feedback is not possible no learning can take place. Often a motor skill can be acquired most rapidly if knowledge of accuracy comes from internal cues. It is common to hear a baseball player say that a particular pitch was solidly hit, meaning that the player had a feeling from kinesthetic cues that indicated solid contact with the ball.

Motor skills are externally controlled to varying extents. The degree to which this is the case can be ascertained by varying the external stimulus situation and observing the effect on performance. Early trials usually involve much trial and error behavior, the correct responses gradually coming to be associated with the relevant stimuli. In training a skill, "guidance" of a skill makes use of the concept of reducing the number of irrelevant cues in the situation so that the learner can concentrate on the relevent cues. Another alternative is to direct the learners attention to the "correct" stimuli. A third type of guidance employs verbal instructions that explain what is to be done manually.

Practice in a motor skill can be of a nature where responding is continuous, or where there is very little time between trials. This arrangement of learning conditions is called massed practice. Opposed to this is the situation where time between trials or between groups of trials is sufficient for rest; this condition is called distributed practice. Measures of the nature of practice can be taken in regard to the time of continuous practice or the interval between practice trials. In experiments in which the time of practice was varied and the time of rest periods was held constant it was found that shorter practice periods lead to better performance. Similarly, where the number of practice trials was held constant and the time of rest periods was varied it was found that longer rest periods lead to better performance. Differences among the groups in the final level of performance were marked, with the subjects having longer rest periods performing better than those with short rest periods.

However, it is important to note that the evidence points to the fact that the decremental effect on performance when using massed trials is largely transitory. If groups of subjects on a massed trial schedule are changed over to spaced trials and spaced trial learners are shifted to massed trial practice, the performance of the groups reverses. Thus, whatever inhibitory factor interferes with performance on massed trials does not appear to interfere markedly with what is learned. It may be concluded that massed trial learning results in initial decrement in performance but does not hinder improvement of performance when the situation is converted to spaced practice.

Verbal sequence learning. In memorizing a verbal sequence, the same basic situation prevails as with a motor sequence. The most usual laboratory situation that has been studied has been the learning of serial lists of nonsense syllables, that is, combinations of letters that do not form words common in the language. An example of such a serial list would be the following: TEV, LAN, QOJ, BIF, ZEN, MEB, ZIK, ROF. The reason for the utilization of nonsense syllables in such study is to permit clear differentiation between learning the chaining of verbal units from the use of concepts. Learning the sequence "A horse is an animal with a tail and a long neck" is a different activity than learning a series of verbal units of equivalent structure like the following: F bojex ur ka pojint mifl k saft mak k beng logg". The first of these sentences is assumed to be capable of repetition from recall after but one trial because we have "taken it in" as a whole, have incorporated the concept sequence. Each element has a meaning that has been well established as well as the familiarity with the grammar of the language. With the second sequence there are no concepts to help in memory, nor is there any easily applicable comprehension of the structure of the units as a result of familiarity with the grammar of the language. Thus, the second sentence should take a great many more trials than the first to become committed to memory. Even the second sentence, however, is not completely devoid of meaning, and experimenters always have to take into consideration the meanings that might result when subjects try to devise methods of learning the whole series. Thus, the learning of a poem involves the utilization of already existing concepts of word meaning and concepts of structure of verbal units as well as the simple association of one word with the next.

As we found in the case of identifications, the learning of verbal sequences is also affected by the occurrence of interference among the individual habits being established. There are strong tendencies for the learner to anticipate responses farther on in the list than the next (correct) response, thus producing what is referred to as "intra-list interference". Many studies have shown that the presence of these interfering tendencies leads to a piling up of errors near the center of the list. Figure 3 shows this effect in the learning of a sequence of 10 three-place numbers. It can be seen that the percent of correct

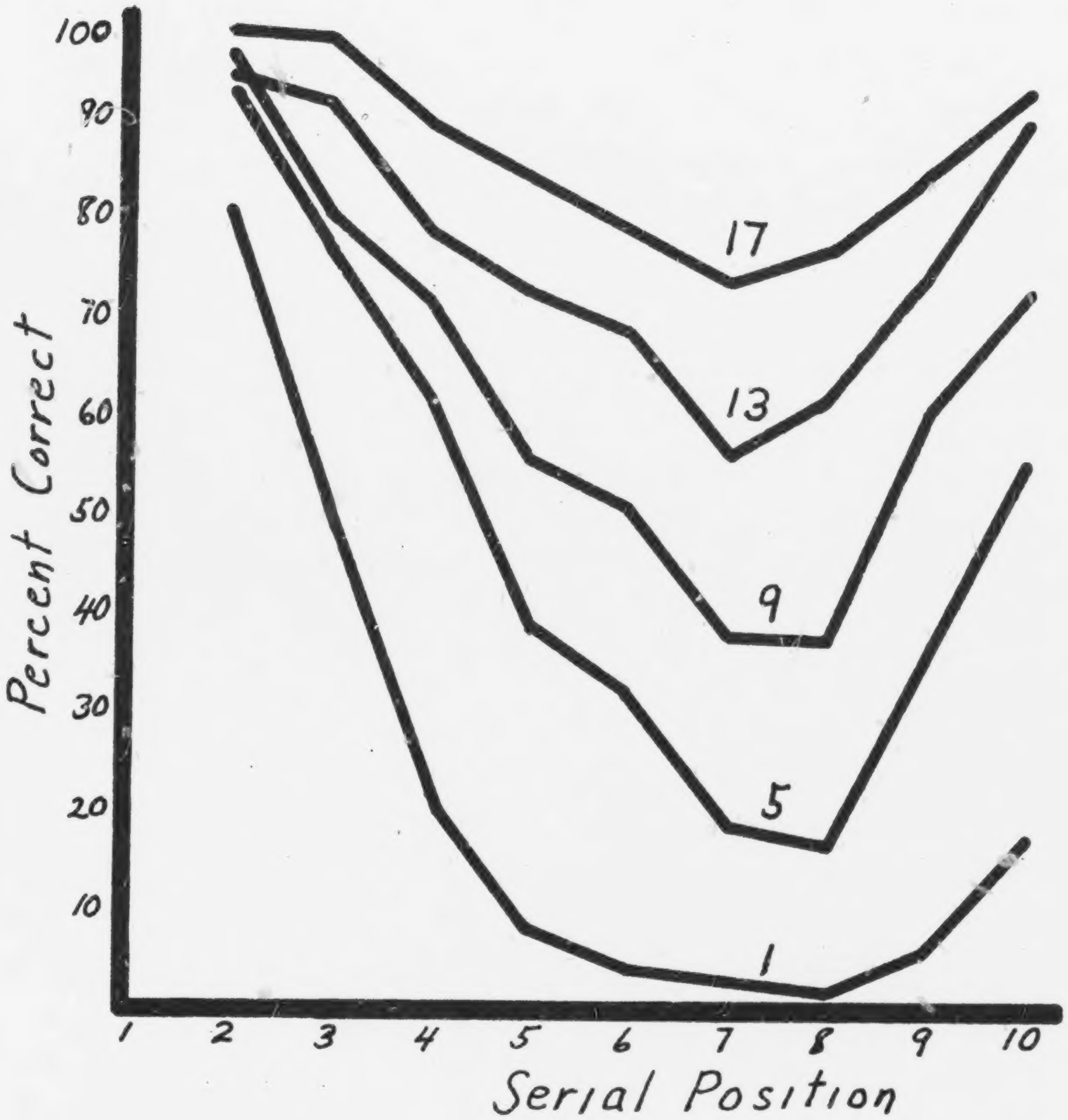


Figure 3. The tendency of the items on the two ends of a sequence to be learned before the middle items is exhibited in this graph, pertaining to the learning of three-place numbers. Correct responses for each serial position are shown for practice trials 1, 5, 9, 13, and 17. As practice progresses, mastery of the sequence appears to proceed from both ends toward the center of the sequence. (Data from Robinson, E. S., and Brown, M. A., Effect of serial position on memorization. *Am. J. Psychol.*, 1926, *37*, 538-552).

responses was initially zero, after the Trial 1, and that this percentage rose progressively on Trials 5, 9, 13, and 17. Correct responding occurred much more rapidly than this, however, towards the beginning of the sequence as well as towards its end. This "serial position effect" is a practically universal finding with many varieties of verbal sequences.

Since the difficulty of learning verbal sequences is to a large extent attributable to interference, sequences of this sort increase in difficulty as they increase in length, presumably because of the greater interference potential of longer lists. Similarly, as we found in the case of identification learning, sequences are more difficult to learn to the degree that their items are similar to each other, because such resemblance increases the tendency for one response to be substituted for another. If one is searching for sequences that are easy to learn, he chooses those which are short and in which the items are least similar to each other.

Concepts and principles.

A concept may be defined as a stored set of connections in which a verbal signal controls the arousal of habits appropriate to new situations, so that the learning of new specific habits is unnecessary. An external stimulus which arouses the same concepts in two or more individuals is called a symbol. These symbols may be situations in the environment, gestures of other humans, facial expressions and words. The last of these comprise the commonest kinds of symbols and it is these that will be discussed with reference to their development.

Symbol learning. Practice with reinforcement is the method by which the child learns words as well as motor skills. Early in his life the child makes a number of sounds at random. Whenever the child utters a sound that is in some way recognizable by the parent as approaching human speech the parent encourages the child by smiling, caressing him or in some way showing approval. These responses are thus reinforced and the child repeats them. Soon the child is able to associate the sound that he makes with the sounds that others make. When accompanied with stimulus objects like a doll the child comes to be able to associate the acceptable sound with object refining his own utterance until it matches that of the parent. Thus the child is able to utter the word "doll" whenever that object is presented to him. The word "doll" becomes a symbol for the child somewhere around the third year, when he is able to associate it with such activities as fetching the doll. That is, the word is not only elicited in the presence of the object but can be uttered in the absence of the object to convey the desire to get and play with it.

The meaning of concepts is not complete with the understanding of how single words come to be associated with their physical referents. Language involves units encompassing larger groups of words in phrases and sentences. Thus, the meaning of one word can be influenced by its position in a larger collection of words, the concept of words in context. An experiment was performed in which words were strung together in collections of differing units to illustrate the development of contexts. The study required people to predict sequences by giving them varying amounts of information. A zero order sequence was established by taking twenty English words at random and placing them one after another. A first order sequence was constructed on the basis of the frequency with which these words are written in English prose. For the second order sequence a word was presented to a subject and he was told to make a sentence using the word. The word that the subject used immediately after the given word was entered into the list and given to the next subject with his being directed to create a sentence using that word and so on until a 20-word sequence was developed. Third-order sequences were obtained by giving subjects two words and asking them to finish the sentence. The next subject was given the second word of the original two plus the first word added by the previous subject. This procedure was followed again until a list of 20 words was developed. Fourth order sequences involved starting with three words, fifth order with four words, and so on. The increase in meaning from zero order to seventh order and then to prose passages is easily seen in looking at Table 2.

Table 2*

Meaning as Conveyed by Sequences of Words
Predicted by Different Individuals in Succession

Zero Order (Random)

betwixt trumpeter pebbly complication vigorous tipple careen obscure attractive consequence expedition pane unpunished prominence chest sweetly basin awoke photographer ungrateful

First Order (Approximating Frequency of Usage)

tea realizing most so the together home and for were wanted to concert I posted he her it the walked

Second Order

sun was nice dormitory is I like chocolate cake but I think that book is he wants to school there

Third Order

family was large dark animal came roaring down the middle of my friends love books passionately every kiss is fine

Fourth Order

went to the movies with a man I used to go toward Harvard Square in Cambridge is mad fun for

Fifth Order

road in the country was insane especially in dreary rooms where they have some books to buy for studying Greek

Seventh Order

easy if you know how to crochet you can make a simple scarf if they knew the color that it

Prose

more attention has been paid to diet but mostly in relation to disease and to the growth of young children

So far the development of representation of objects by words has been discussed and the sequential nature of language due to frequency of words and probability of their occurrence in relation to each other. Generalization of concepts is important in that it permits the tying together of many diverse stimulus situations by common underlying factors. Generalization permits the transcending of specific habits. Further, there are different types of concepts that develop in human activity. Class concepts such as "table", "up", "father" and so on are developed early. Rules, which are concept sequences, enable us to generalize from the specific to new situations, such as "Look both ways before crossing the street". Abstract concepts develop to refer to classes such as "beauty", "justice", and "democracy" and these appear somewhat later in development.

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* Contents of Table 2 from Miller, G. A., and Selfridge, J. A., Verbal contest and the recall of meaningful material. Am. J. Psychol., 1950, 63, 176-185.

Conditions of concept learning. Although there have been many studies of concepts, it is clear that in this area the principles of learning are not yet as well founded on firm experimental evidence as is the case with the learning of simpler performances. We must do the best we can, then, to interpret such evidence as does exist.

A concept which classifies stimulus objects appears to be subject to the same general rules in its learning as is an identification response. If the task which faces the student is one of learning to classify "organic compounds", or "diodes", or "integrals", we expect that such learning will be subject to the conditions of motivation, practice, and reinforcement which characterize other types. In addition, the effects of interference on the learning of classifications are also obvious. Just as identification learning requires the reduction of confusion between one stimulus object and another, so does the acquisition of class concepts require the reduction of confusion between one class and another. Accordingly, the basic form of learning may be expected to be one which contrasts "correct" and "incorrect" responses.

When we turn to the learning of rules and principles, however, there are still other things to be considered. First, the learning should engender maximal generalizability on the "stimulus side". This means that the concepts to be acquired should be presented in as wide as possible a variety of stimulus contexts. As a simple example, if we want a student to learn to simplify algebraic expressions wherever he meets them, he should learn to do this in response to a great variety of expressions. Using only x and y as variables results in a lack of generalizability to expressions containing a, b, sin x, H, and so on. Second, one needs to insure that generalizability is adequately taken care of "on the response side". Again using a simple example, the concept "add" will be of limited usefulness if the individual has acquired only the response sequences associated with adding integers. He must also be able to reinstate, to the concept "add", the very different responses required in adding decimals, fractions, radicals, etc.

Finally, and of critical importance to concept learning, is the fact that concepts must be capable of internal arousal by the individual himself. If we always present him with problems like "Add the following:" we cannot be sure that he will in fact learn "add" as a self-arousable concept. The solution appears to be, that learning must include situations like "What do you have to do to the following?", to which the correct conceptual response is "add". It is evident that the learning of concepts involves principles that go much beyond those required for simpler kinds of performances.

Retention

The function of memory permits man to profit by experience, so that he typically acquires higher and higher levels of performance capability. Increasing numbers of skills are developed as a result of being able to retain what was previously acquired through the learning process. However, all that is learned is not retained over periods of time. There are losses; and the prevalent theory is that these losses in learned material are the result of ongoing neural events, rather than because of some sort of physiological degeneration. Therefore it becomes as important to understand the process of forgetting as it is to understand the nature of learning. In some respects, forgetting helps the individual in his adjustment to his environment, by permitting him to undertake new learning without the necessity of first unlearning old modes of operation. Since man is continually required to learn new habits and skills with which to deal with his environment, it is convenient that he can forget those aspects of his learning that are not in use. Thus man is more flexible as a result of being able to forget some of the things that he has learned.

The Nature of Forgetting

The essential facts of forgetting in a simple habit can be illustrated by referring to the learning of rats in the runway situation discussed in a previous section. A number of rats were trained in this situation until they were able to make three consecutive responses of less than five seconds per trial. Then the animals were segregated into groups that were again placed in the starting box after three days, seven days, fourteen days and twenty-eight days respectively. The number of trials was counted that was required for each rat to relearn to the criterion of running to the food box in less than five seconds on three successive trials. By comparing the results for each group it can be determined just how much of the problem was retained or forgotten over these periods of time. The nature of the curve obtained by plotting these results indicates that forgetting increases in a negatively accelerated fashion with the passage of time, with most of the forgetting occurring in the period immediately following the initial learning.

The German psychologist Ebbinghaus performed many experiments on human memory late in the nineteenth century. Using himself as a subject, he learned lists of nonsense syllables to the point where they could be recited perfectly once. After a number of days he counted the number of trials that were necessary to relearn the lists. By taking the difference between the number of trials needed to learn the list originally and the number of trials needed to relearn the lists he arrived at a figure that was called "savings due to retention." The results indicated a rapid increase in forgetting for the first few hours after original learning followed by more forgetting but at a slower rate lasting for a few days. The same general relationship was obtained with this sequential performance as with the simple habit, that is, a curve following a negatively accelerated course. This classic finding is illustrated in Figure 4.

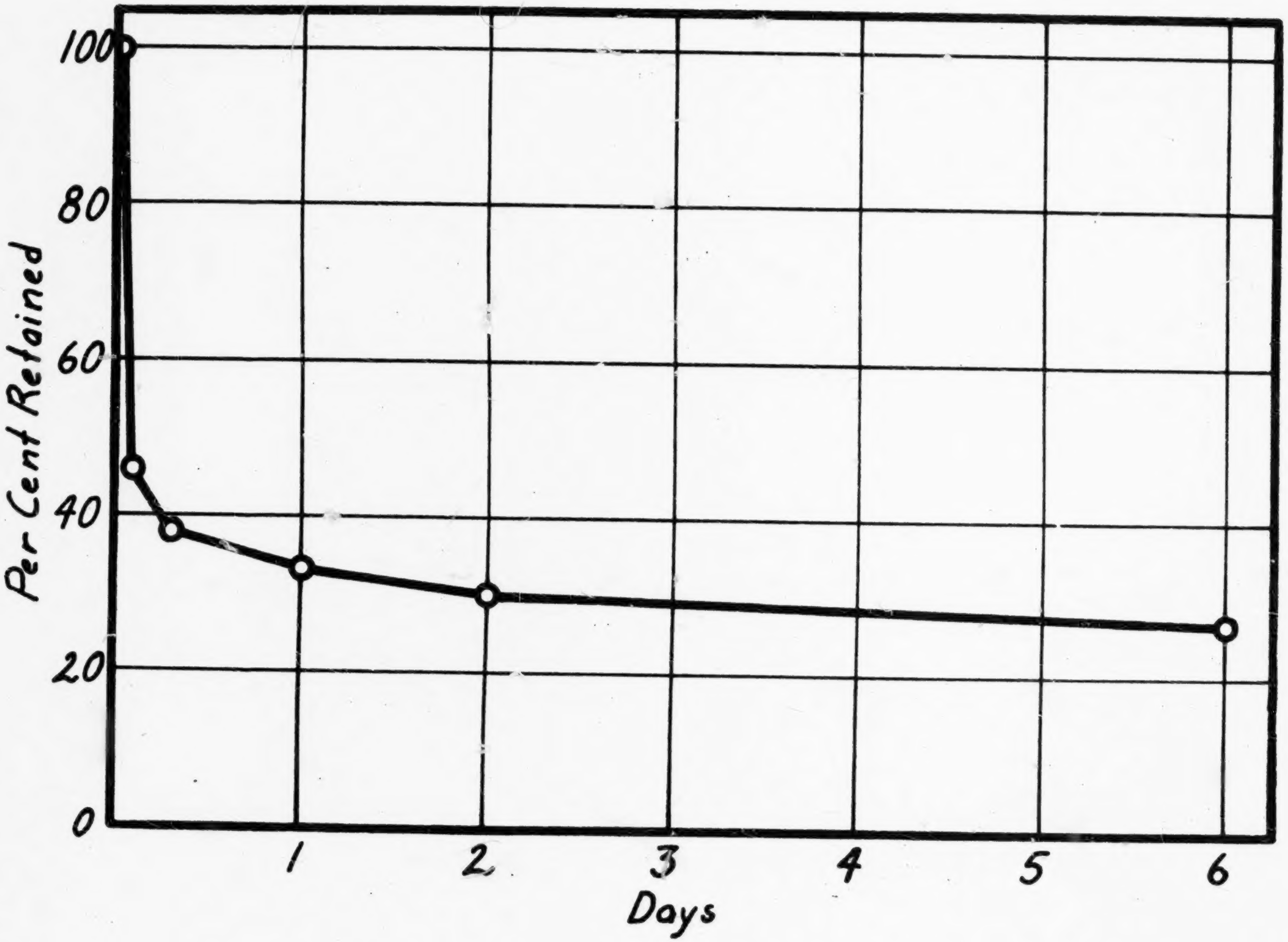

Figure 4. The curve of retention for sequences of nonsense syllables, obtained by Ebbinghaus.

Measurement. Two methods of measuring retention that are most commonly employed are the measure of recall and of recognition. The measure of recall requires the individual to respond to the same stimuli which were present with the original learning by reinstating the responses that were learned to those stimuli. This method is commonly utilized, for example, when one asks the learner to recite a previously learned verbal sequence such as a poem or prose passage. Recognition provides a somewhat different measure of retention; the individual may be able to recognize a stimulus object when he no longer is able to make an identifying response to it. The method of recognition requires that the subject distinguish between a number of stimuli picking out the stimuli that he previously responded to from those that he did not encounter previously. In the case of both these methods, the measure of retention is simply the amount or the proportion retained. Still another method of measurement uses the number of trials required to relearn some previously learned task. In connection with this measure the term "savings" is employed. The amount of savings is measured by taking the difference between the number of trials needed for original learning and for relearning. Often savings is expressed in terms of percentages. Thus a high percentage of savings would mean high retention and low forgetting while a low percentage of savings would indicate low retention and high forgetting.

Factors Affecting Retention

Degree of learning. When an activity is practiced the performance level gradually rises to a degree that may be considered "adequate" and additional practice increases the level of performance only slowly. This increased practice may not show its effect on measures of learning, but may have a pronounced effect on the degree of forgetting. Experiments in verbal sequence learning indicate that retention increases with the amount of original practice. This relationship continues to hold well beyond the point where increased practice shows no improvement in performance on the original learning. Practice continued beyond the point where it is directly evidenced as increased performance is called overlearning. This overlearning enters into the learning of many types of activities. Because of this effect, two individuals with the same level of performance at any one time may not exhibit the same degree of performance at some time in the future. Thus a newly trained person may be able to exhibit a performance that is not greatly different from that of a more highly practiced person, but if both persons cease performance of the task for a period of time and then return to it, the person with the greatest initial practice would be expected to retain more.

Nature of activity. Verbal sequences, concepts, motor skills, and simple habits are not forgotten at the same rates. It is difficult to equate the original learning of such different activities as learning a poem and learning to swim, thus making it difficult to make comparisons of the retention of such tasks. Experiments attempting to control the amount of original learning on different activities, however, have indicated large degrees of difference due to type of activity. It appears that motor skills of the continuous nature as opposed to discrete motor skills are most resistant to forgetting. An activity like swimming may remain proficient to some degree even without practice for a number of years. Concepts have a long period of retention as measured by recall of the meaning of prose materials. Verbal sequences, particularly of nonsense material show the greatest degree of forgetting over time. Two conditions that determine to a large extent the degree of retention of materials are (1) the amount of original learning and (2) the amount of rehearsal between original learning and tests of retention. Retention of any particular performance may be due to the degree to which it was originally learned or to the amount of rehearsal that took place during the time after the original learning.

Interference. The learning of a second task following a first learned activity has been shown by many studies to interfere with the retention of the first task. For example, if a number of subjects learn a list of nonsense syllables, then learn a second list of similarly constructed syllables, the first list will prove to be difficult to recall. The comparison is made with subjects that are asked to recall the first list without having learned the second list, but with an equivalent amount of time elapsing between original learning and recall test for both groups. This phenomenon is called retroactive interference. The amount of retroactive interference produced is directly related to the degree of similarity of the two tasks to be learned. Overlearning, however, reduces the effect of retroactive interference. For example, the learning of two lists of foreign words causes interference, but such lists do not interfere with the recall of words in the native language, which have been overlearned. Another form of interference is called proactive interference, which refers to the effect of previously learned tasks on the retention of a given task. It has been shown, for example, that the recall of a verbal sequence is reduced in direct proportion to the number of verbal sequences of the same sort learned previously. The evidence shows, then, that interference works both ways in its effects on retention.

Inactivity. Several studies have shown that the effect of retroactive interference can be reduced by reducing the amount of activity engaged in after learning. In one study a series of ten nonsense syllables were learned and then some subjects went to sleep immediately while others remained awake and active on other tasks. Retention was measured for the subjects after 1, 2, 4, and 8 hours of sleep. The waking subjects showed increased forgetting over the eight hour period, with the expected sharp initial loss in retention and then a more gradual loss from one to eight hours. For those who went to sleep, there was also a loss in retention after the first hour but not as great as for the waking group. After the second hour, however, retention remained about the same through the eighth hour. It is difficult to reduce the level of activity to zero in human beings immediately after learning, because they do not go to sleep immediately. In an experiment employing cockroaches as subjects a simple habit was learned, namely, avoiding the darkened end of a lighted alley on penalty of shock. Immediately after learning half of the subjects were induced to enter a narrow cone lined with soft material where they remained immobile. The other animals were placed in a cage where they engaged in moderate activity during the retention period. It was found that retention was markedly greater for the immobilized animals, although some forgetting took place. It appears from these results that interference accounts for the greater portion of forgetting, but not for all of it. Learned activities apparently decay to some extent with the passage of time. This decay process is probably most important in the time immediately after learning, while active interference accounts for the forgetting that goes on over a much longer period of time.

Transfer of Training

The ultimate goal of learning any activity is to be able to apply the results of the learning to a variety of other situations encountered in normal daily living. Vocabulary in a foreign language is not memorized merely for the purpose of repeating it on an examination but to form the basis of being able to read, write and speak in another language. The usefulness of any learning therefore can be determined by the extent to which such learning can be transferred to new situations.

The Meaning of Transfer

Transfer of training is the effect on a new activity of previous learning. There are two basic types of transfer. The first is called positive transfer, which indicates that practice on one task facilitates the performance of another task. Negative transfer is the second type, and occurs when practice on one task hinders the development of skill on a subsequent task. An example of this situation would be provided by a person learning to type on one typewriter and then shifting to another with an entirely different arrangement of keys. The habit interference that develops would show up as errors in the early period of training on the new typewriter. If the degree of interference is so great that it takes longer for a person to learn to use the new typewriter than it would take if he had no previous training, then we have an example of negative transfer.

Conditions of Transfer of Training

As we have pointed out, transfer is a very common occurrence. In fact, learning is the important process that it is largely because of transfer. When one acquires a new habit, skill, verbal sequence, or concept, the learning which takes place is truly effective only because this behavior can be exhibited in a variety of new situations. If the effects of learning were confined to specific situations, human behavior would indeed be limited in scope. Under what conditions does learning transfer beyond the specific situation? The basic principle is that transfer between two tasks occurs to the extent that they are similar. There are a number of ways, however, in which the similarity of the initial learning situation and the final performance can be exhibited, and we shall consider these next.

Identical elements. One measure of similarity is the number of "elements" that are common between two tasks. This measure holds particularly well for identification learning in which the identical elements are the individual identification habits. In this case the greater the number of identical elements the greater the degree of positive transfer. An experiment demonstrating this was performed using sorting behavior with a pack of Flinch cards. Nine cards numbered 1 to 10 (with number nine not included) were to be sorted into nine compartments. Eight practice trials were employed and the time for sorting was measured. One group of subjects then continued the operation for two more trials while a second group was given a task in which six of the responses were the same and three were altered to new positions. Other groups learned a new order involving six and nine changed responses. The first group showed some improvement on the two extra trials; while the group that transfered 6 identical elements showed diminished transfer of training. The group using 3 identical elements showed an even smaller amount of transfer, while the group using no identical elements showed practically none. The results are shown in Figure 5.

Stimulus similarity. In learning a specific response to a specific stimulus some degree of generalization takes place so that physically similar stimuli become attached to the same response. As these similar stimuli are made less and less like the original stimulus the strength of the response is weakened. In one experiment the GSR (galvanic skin response) was conditioned to a 1,000 cycle per second tone. On testing for responses to stimuli of tones other than 1,000 cycles it was found that the strength of the response varied inversely with the distance from the originally conditioned stimulus. This phenomenon has been found to occur in animals as well as human subjects on a number of simple habit-learning tasks and is called stimulus generalization. It is considered to play an important part in most circumstances involving transfer of training.

Transfer of concepts and rules. The condition of the transfer of a concept from one situation to another provides perhaps the most striking example of the condition of transfer of training. A rule that is learned in one situation can be applied to a new situation with apparent ease; such transfer is usually close to 100 percent. The psychological

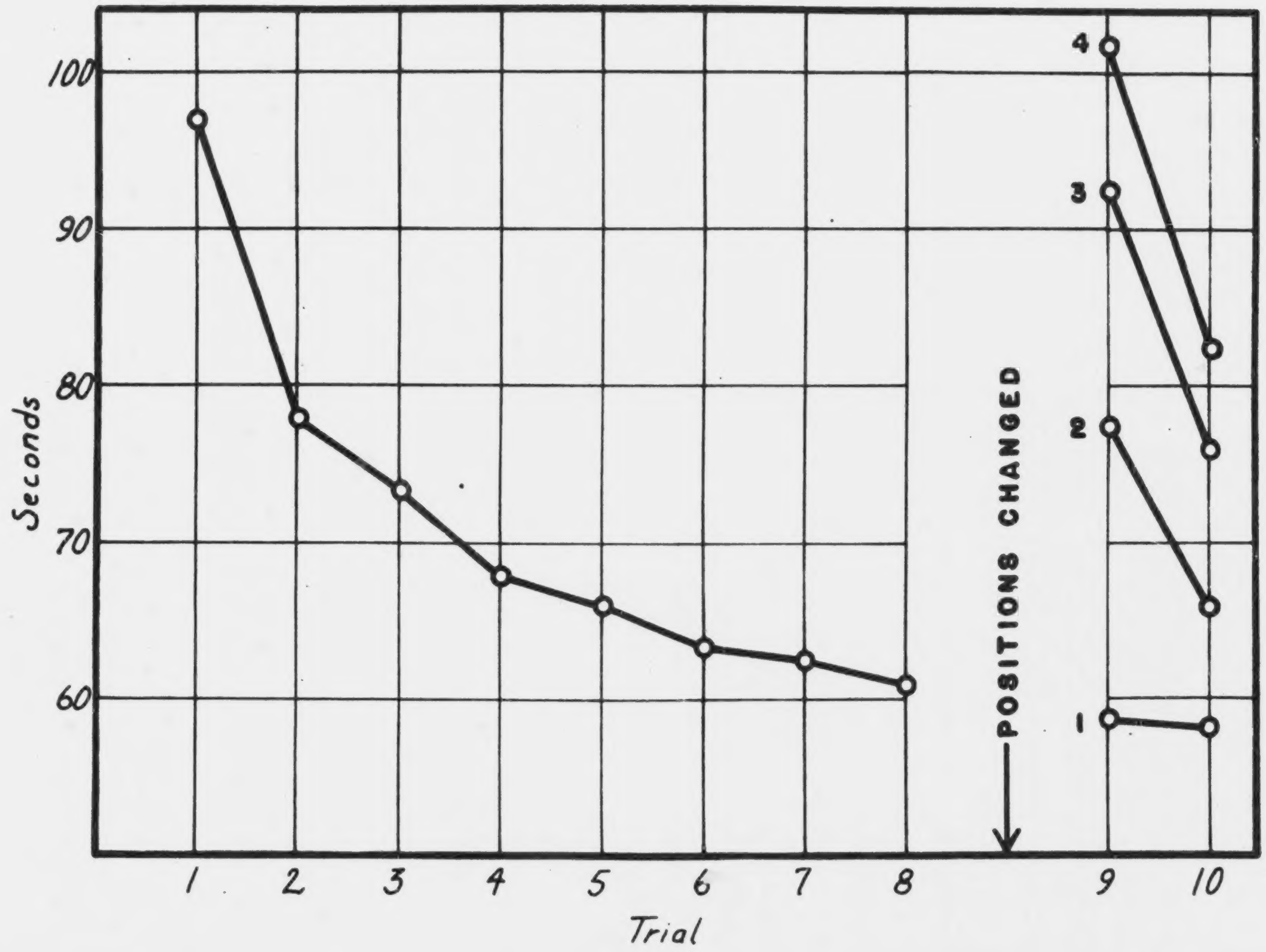

Figure 5. Transfer as related to the number of common elements in the initial and final tasks. In the transfer condition, Group 1 continued the same task; Group 2 had 3 out of 9 positions changed; and Group 4 all changed. Positive transfer is shown to decrease progressively as the number of identical elements (sorting positions) is reduced. (Data from Crafts, L. W. Transfer as related to the number of common elements. J. gen. Psychol., 1935, 13, 147-158).

literature contains a number of demonstrations of transfer of rules or principles. In one experiment a group of boys was given the task of hitting a target under water. Some of the boys were instructed in the principles of light refraction as it applies to the apparent displacement of an object from its real position when under water. The other boys were given direct practice without this instruction. After both groups could hit the target equally well the depth of the target was changed. Under these changed conditions the boys with the instructions involving the refraction concept performed much better than did the other group. In other words, transfer to the new situation was mediated by a set principles.

Measuring transfer. The degree of transfer, either of the positive or negative sort, is calculated as the difference in performance on a given task by those subjects that have had the benefit of previous learning, and by those who have had no such previous practice. Typically, one group of subjects learn some activity (Task X) and then learn another task (Task Y); a second group of subjects simply learn Task Y directly without previous training on Task X. Now by comparing the number of trials to learn Task Y for the two different groups it can be determined if the learning of Task X had a beneficial effect, no effect, or a detrimental effect on the learning of Task Y. Suppose one group takes 15 trials to learn Task Y, while another group that has had previous training on Task X takes 5 trials to reach the same criterion of performance on Task Y. The amount of saving due to learning Task X can be said to be 10 trials. This can be expressed as a percentage of transfer by taking the relationship between the amount of savings and the total amount of trials needed by the group that received no prior training. In the example used here, the percent of transfer would be 10/15 or 66.7 per cent.

Transfer and education. Transfer is recognized in education for its relevance to school learning situations. Educators frequently stress the importance of "teaching for transfer". School training is sometimes designed so that there will be maximum transfer to real life situations, as well as to further learning in academic settings. For example, elementary arithmetic may be taught using problems that directly relate to situations like balancing a budget or paying a grocery bill. There is always the problem, however, of choosing the kind of materials that most efficiently help in reaching the goals of good education. For example, does requiring the child to learn to recite a poem help his understanding and appreciation of poetry in general? Does the mastery of the Latin language help a child to understand and apply the principles of English grammar? Or does it give him a better concept of the structure of languages than would the learning of a modern language like French or German? These are the kinds of questions raised by the idea of transfer of training in educational settings.

The two basic principles of transfer we have summarized from the evidence of experimental studies are still the best rules we have for application to educational situations. Certainly it is of great importance to design learning situations for maximal positive transfer. Usually this means transfer to an ultimate performance in a job, but it may equally well mean performance in advanced courses. We restate these principles here:

1. Transfer will be greater the more the performance demanded in the learning situation resembles the finally required performance. If Johnny can't read, this probably means that whatever "learning to read" has meant in school, it does not resemble the final task in some crucial respect. If Johnny can't spell, the chances are the performance of spelling new and unfamiliar words has not been a part of the learning situation in school.
2. Transfer will be greater, in the sense of having wider applicability, the more the learning situation has encouraged generalizability. The learning of principles, as opposed to simpler performances (sometimes called "rote" learning) is certainly part of the answer here. But more than this, as we have seen, is the fact that generalizability may be insured by making the concepts that are learned truly adequate ones. To be adequate, they must be accurate (not confused with other concepts), and they must be learned in a variety of stimulus contexts.

Motivation and Learning

The Nature of Motives

The concept of motivation is used to explain the activity and direction of behavior. Motivation functions as an energizer; it is involved when the human being is activated to use his verbal, thinking, or motor skills. Motivation can be viewed as the "power" without which the behavior system fails to work.

What conditions are necessary to produce motivation? Why are particular activities energized at certain times? What channels the energy into specific behavioral acts? These are questions relevant to the nature of motivation.

At the most basic level, motivation results from the tendency of living organisms to maintain constant states of equilibrium in their internal conditions. This principle of the regulation of the internal milieu is called homeostasis. Homeostatic mechanisms function, for example, to preserve the proper balance of oxygen and carbon dioxide in the blood, and to maintain a constant internal body temperature. To achieve and maintain internal states of equilibrium, the organism must often interact with the environment. When he does this, the behavior can be identified as being under the control of some internal need. The term motivation in general, then, refers to behavior that is aroused by some kind of disequilibrium within the organism, and is directed toward goals which can restore this equilibrium.

Motivation has various aspects; it is convenient to describe these in terms of a sequence of events with three stages. First, there is the need, resulting from disequilibrium. This need may be physiological or it may be acquired through learning. The second stage of the motivation sequence is the behavior which results from the need. This behavior may vary from reflexive responses to highly complex learned acts, depending upon the need aroused. The final stage is the goal or incentive toward which the behavior is directed. The goal response results in the satisfaction of the need; that is, equilibrium is reestablished.

Some motives of man can be shown to have a direct relation to states of physiological disequilibrium. These are called the primary drives, and a list of them would include hunger, thirst, sex, muscular exercise, sensory stimulation, among others. Man shares these primary drives with other animals. Each one of them may readily be shown to energize behavior in accordance with the cycle Need ---- Behavior ---- Goal which we have described.

The great variety of human want plus desires, however, are not accounted for by the primary drives. It is clear that a large part of human motivation is acquired as a result of particular interactions of the person with his environment and the consequent learning which occurs.

Learning a new motive is not particularly difficult; in fact, the individual may not even be aware that he has learned a motive. Under proper environmental circumstances, animals can acquire quite unusual motives. For example, we typically consider making money as a motive. Acquired through learning and as a distinctly human phenomenon; yet the fact is that animals can, and in fact have, acquired such a motive.

More specificially, chimpanzees were taught to obtain a desirable food by inserting a poker chip into a vending machine. After a while the animals came to desire the chips themselves even though these could not be used immediately to get food. Such acquired motives can also be quite specific. Chimps which had been taught that food was obtained by using a red chip and water by using a blue chip, would work harder for the appropriate chip when different degrees of deprivation were introduced. Thus, if more hungry than thirsty, the chimp would pull a heavier weight to secure a red chip than a blue one. These interesting studies demonstrated the acquisition of new motives: poker chips became incentives because of their association with the reduction of a primary drive. In an analogous fashion other originally "neutral" situations or stimuli can become goals. The principle involved is that stimuli which regularly precedes the satisfaction of a primary need may themselves become goals.

The young child learns new motives in a similar manner. The mother, in her role of satisfying the child's basic needs in feeding and comforting him, comes to be a loved object through her association with these primary drive reductions. While adult motivational patterns are more difficult to unravel, presumably they have developed in the same way. Thus, the foundations of the aggressive or submissive tendencies of adults were probably established in the patterns of early need fulfillments. Advertising campaigns continuously try to have us acquire new motives through association with other stimuli which satisfy certain of our needs.

Many aspects of motivated human behavior cannot be explained in terms of a connection with primary needs or in terms of simple learning and generalization. Some social behavior is learned through the fulfillment of primary needs; these acquired social motives, however, then become a basis for further learning. In fact, these social motives may even take precedence over primary drives; such is the case, for example, when a person gives up sex for religious motives. Considerable regulation over man's behavior is achieved by rewarding certain social motives.

It is not possible to describe all the kinds of social motives which a human being may acquire, because there is a great variety of them and many of them are quite specific. Some of the more important and prevalent motives of our culture have been identified as follows:

1. Affiliative needs. Most people have strong motives to live together, play together, and work together. This potent need for affiliation with other people has been shown to exert a strong influence on industrial workers. One can expect it to be evident in educational situations as well. Performing laboratory exercises together, for example, commonly has the effect of developing morale among the students in a course.
2. Status needs. Another set of acquired needs are those of achieving personal power, prestige, or status in one's group. Such needs are of course common in a group of students, and are often fulfilled by means of fraternities, student organizations, and within other less formal student groups. Status needs can conceivably conflict with educational aims, as happens when high status goes with a "C" rather than with an "A". However, this may not be a very common phenomenon nowadays. The cultivation of needs for professional status, however, is often a way of achieving positive student motivation.
3. Achievement needs. People differ markedly in their need to achieve, in a general sense. It has been shown that a generalized need of this sort accounts for the fact that people with lower degrees of skill often surpass others more talented. Specific needs for achievement, sometimes called "levels of

aspiration" can often be successfully established within the learning situation itself. Standards of performance provide important means of utilizing this aspect of human motivation. When these are combined with "experiences of success" within the learning situation, they become a powerful tool for the establishment of effective learning conditions.

4. Acquisition needs. Acquisitiveness for goods, personal possessions, money, property is an important learned motive in our society, although it is not universal in all human societies. For some people, a college education may be merely a convenient step on the road to fulfilling motives of this sort. Such motives are often the basis of student behavior characterized by "working for grades", and tend in some instances to militate against a desire for thorough understanding and mastery of the knowledge to be learned. Acquisition motives are not "bad" in themselves, and they often constitute a dependable source of student motivation.

Incentives

We have been discussing the motives that impel people to behave in certain ways. As we have pointed out, the total sequence of motivation includes the need state, the kinds of behavior set in motion by this state, and the goal response which satisfies the need. And we have pointed out that in acquired motives especially, a variety of goal responses may satisfy the same need. Now we shall take a look at the incentive end of the motivation sequence.

Incentives are often used to control the behavior of other people. Parents continually use incentives to control and direct the behavior of their children. Employers use incentives to get people to work in desirable directions. Political parties use incentives to guide voting behavior. Similarly, the use of incentives to affect the behavior of students is a part of the teacher's job.

Rewards and punishments. Verbal rewards or punishments, in the form of praise or reproof, are a frequently manipulated class of incentives. Status motives are particularly affected by these incentives.

In general, praise has been shown to be a more effective incentive than disapproval. This is illustrated in a study performance of school children in solving arithmetic problems over a period of several days. After 5 days the praised group continued to improve while the reproved, ignored, and control groups did not. Various studies carried out with college students have also indicated that praise for past performance is superior to most forms of disapproval. Private reprimand was the only method of reproof which more often facilitated rather than impaired performance. Disapproval in the form of public ridicule or sarcasm is particularly ineffective as an incentive. It may be that such disapproval merely acts to increase the need, rather than to satisfy it.

We have seen that reinforcement, sometimes in the form of a concrete reward, strengthens the habits being learned. At one time, psychological theory held that punishment worked in the opposite way, that is, weakened learned connections. But this has many times been shown to be untrue, according to the evidence. It can be shown that punishment blocks a response, but this effect is a temporary one, and the acquired habit continues to manifest itself after the block has been removed. So far as unlearning is concerned, the removal of reward (extinction) is an effective way of weakening a habit, but punishment is not.

It may also be noted, however, that the provision of a block to behavior, as in punishment, may force the individual to learn something else, something new. If such block is used in connection with opportunity to acquire a new habit or skill, the effects may indeed be what is desired.

Learning and Education

Now that we have described the various specific topics which may be considered a part of the psychology of learning, let us try to take a global view of the process of education. We shall want to consider particularly how learning is carried out in an educational framework, and what are the roles of the student and the teacher in this setting.

It is of some considerable usefulness to consider the educative process as a system, a word which we used in the introduction to these materials. Let us now see if we can convey a greater meaning by this term, in the light of what the student knows about the learning process. The central focus of this system of education, as we mentioned previously, is the human learner. Presumably, we now know something about the kinds of events that are going on inside the learner, even though we may be unable to explain how they take place. We can consider that the human learner is placed in an environment which determines the input, or stimulation. What we expect as an output, or set of responses, is some effects which can lead us to the conclusion that effective learning of knowledge has taken place.

The educational "system" has three major components--the human learner, the teacher, and the content materials of the course or curriculum. It is apparent that what one wants to achieve by means of education is to arrive at the point at which the learner demonstrates that he "understands" the content. By this is meant not simply that he can recall it, but rather that he can put it to use in new situations. The job of the teacher, then, considered in its broadest sense, is to so arrange the stimulus situation affecting the learner that this outcome will inevitably come about. This is obviously a very demanding and responsible job. In other words, the teacher's job can be summarized as one of establishing the conditions for effective learning.

Conditions of Effective Learning

What are the various operations performed by the teacher in establishing conditions for effective learning? It should now be possible to list and describe these operations in a somewhat systematic way.

Motivational conditions. Most students begin a course with some degree of positive motivation. There is a motive to explore something new. There is an affiliation motive--other students have taken and are taking this course. There might even be prestige involved in studying this particular subject-matter. Almost surely there is motivation to achieve, whether it is simply to achieve a good grade, or a more praiseworthy aim of attaining a degree of professional competence.

The teacher's task is to make use of the kinds of motivation which will further the aims of the educational system. He manipulates incentives in such a way as to reward the kinds of behavior which appear to be based on useful motivation, and withholds reward for the kinds of behavior which are not. In a sense, part of what is being learned in the educational setting is motivation itself. A number of specific motives have to be acquired; for example, the motive of meeting deadlines, the motive of valuing knowledge for its own sake. The task of using incentives for desirable motivation begins with the first meeting of the class, and first impressions are indeed very important. However, this operation needs to be carried out frequently, throughout the course. Basically, the teacher does it by talking about the content of the course, and relating it to the goals of students' motives.

In dealing with achievement motivation, the teacher has a particularly important task in defining goals and standards for the course of study. These need to be both general and also highly specific. On the one hand, the teacher needs to tell students about the general aims of the course in order that the student can relate his current activity to career and professional goals. "What has studying atomic theory to do with being an engineer?" is a kind of question the teacher needs to answer as well as he can. No source of achievement motivation should be overlooked. On the other hand, specific goals must also be carefully set and communicated to the student, if achievement is to be given proper emphasis. Is the student asked to prepare a paper or report? If so, how long should it be, what approach should it use, and when is it due? Are laboratory reports required? If so, what form should they have, in how much detail should equipment be described, and what are the criteria of excellence? It helps sometimes to be somewhat informal and even casual about teaching. But such a manner should not be applied to these standards, which are an extremely important part of the teacher's job. Setting standards is the fundamental means the teacher has of applying and using achievement motivation.

Attitudes and sets. Establishing desirable attitudes in students is not a matter which is wholly distinguishable from using motives, which we have just discussed. The student needs to acquire the kinds of concepts which affect his behavior by controlling a variety of responses he makes to a course or a set of courses. These are his attitudes. The teacher establishes and strengthens these attitudes when he talks about the work of the course. For example, he may establish an attitude connected with the need for affiliation, when he talks about "what we are going to do together". Similarly, he can undertake to establish desirable attitudes which provide the basic conception the student has of fulfilling his status needs, or his acquisition needs. All of these are brought about by "talking about" the course and its aims, rather than by communicating specific content. Taken together, they are what is meant by "desirable attitudes".

A particular meaning of attitude, or set, also needs to be emphasized here. One of the important things to be accomplished by the teacher is to establish a task set. Usually, this is done by telling the student what it is he is going to learn, before he undertakes to learn it. Evidence indicates that a task set is an exceedingly important condition for learning. Not only does the teacher need to establish a general task set covering an entire course, but he also needs to provide task sets of increasing degrees of specificity at the beginning of each laboratory or class, and even down to the specific individual group of identifications, skills, or concepts which are being learned at a particular time. Informing the learner about what he is going to learn is an effective way of preparing for learning itself.

Conditions of learning. The implications of our previous discussion of the conditions of learning should perhaps be pretty clear. The major point to be made is that, while there are some general conditions for learning of any sort, the most important thing to be decided is what kind of performance is learning wanted for? The arrangement of specific learning conditions is something that requires an answer to this question.

We saw that there were conditions which appeared to apply to the learning of all kinds of performances. The establishment of motivation is the first of these, which we have just discussed. A second condition is the provision of practice, or repetition. An attitude of dislike for such ideas as "drill" and "rote learning" should not blind the teacher to the fact that a certain amount of repetition appears to be required for all learning. The simpler the material, the smaller is the amount of repetition required. If the teacher can arrange material in a sequence which proceeds in stages from simple to complex, so that each stage is relatively easy, then the psychologist will certainly applaud. He will expect, too, that learning material arranged in this way will require relatively small amounts of repetition within each stage. But some amount of practice must inevitably be present, if learning is to occur.

It should also be noted that repetition need not be "dull and repetitious". We have seen that variety in stimulus material is a condition favoring generalizability (a criterion of effective learning), as is also true of variety in responses. Repeating learned connections in some exact duplicate form trial after trial is not necessarily a desirable learning condition. But it remains true that practice of the essential things to be learned is necessary for learning. Repetition in this sense is essential.

A third condition is that of reinforcement, or, as it usually occurs in human learning, "knowledge of results". We have pointed out that the reason why such reinforcement works is not well understood. But the fact that it does work is something that has nearly universal agreement. Accordingly, the teacher's task is to arrange conditions in such a way that knowledge of performance will be available to the student every step of the way. Obviously, this means much more than simply giving students a grade at the end of a course, or even after each examination. So far as we know, learning will increase in effectiveness to the extent that knowledge of results is provided to the student frequently and in detail. If possible, this means that such feedback should be given not only at the end of, say, a laboratory exercise, but on many occasions during the exercise. Reinforcement can be provided not only by a grade on a test given at the end of a class, but also by the information provided by the teacher during the class period. It seems difficult, in fact, to conceive of a teaching situation in which one could say there is too much "knowledge of results". Usually, there is altogether too little.

Finally, the teacher arranges conditions of learning to be "free of distractions". Of course, this is done in many specific ways. Classes are conducted under relatively quiet circumstances. (They never really work well outdoors on a spring day, despite what students may say about this arrangement). Laboratory partners are set to work in relative isolation from others. And presumably, the studying that is done outside of class demands some degree of freedom from distraction, if it is to be done well. There seems little doubt that noisy roommates, and television, are much more effective as distractors than is gentle radio music.

Having insured the conditions for these general factors, the teacher may turn his attention to the specific question mentioned above, namely, what is it that is being learned? Let us consider here what it is that the teacher can do for each kind of human performance.

1. Discrimination. Since these activities do not depend on learning, what the teacher can do best is to know enough not to try to teach them. Visual acuity cannot be improved by training, in contrast to estimation of length, which surely can.

2. Identifications. It is well for the teacher to recognize what a fundamental and pervasive kind of performance this is. Learning "what things are", and "how to locate things" is usually the first stage in learning any subject whatsoever. Efficient learning appears to require primarily a program in which "right" and "wrong" instances are contrasted. The "things" to be identified come to be increasingly differentiated by such learning. In other words, identifications become more and more accurate. Cosines are confused with cotangents to a decreasing extent; or density with specific gravity; or potassium chlorate with potassium chloride.

3. Verbal sequences. The teacher may want to avoid having students learn formulas of strings of numbers to the maximum possible extent. However, one should not lose sight of the fact that sequences can be learned, that they do no active harm to the learner, and they may be a great convenience. Simple examples with which all of us are acquainted are the square roots of small numbers. We may save much time if we have memorized the square root of 2 as 1.414, rather than having to look it up each time. Originally, we had to learn it, just as we learned other verbal sequences.

Practice is of course a necessity in the acquisition of verbal sequences. The difficulty of learning such sequences arises principally from intra-list interference, as we have seen previously. How does one reduce such interference? Of course, the first answer is--choose short sequences. Difficulty of learning sequences increases geometrically with their length, according to one study. If one must learn long sequences, they will be acquired more readily by breaking them up into smaller chunks.

4. Motor skills. The learning of motor skills is subject to much the same conditions as verbal sequences. But among these is the

condition of providing the proper stimulus situation. In teaching motor skills, the teacher must bear in mind that an important portion of the stimulus situation comes from the movements of the muscles themselves. This is why one can't accomplish too much by showing an individual how to perform, and perhaps still less by telling him how. He must do it himself, in order that the proper stimuli are provided by his own muscular movements. This is the reason for the emphasis on "form" and "stance" by instructors of athletic skills like golf, tennis, or baseball. The teacher of engineering students may be similarly concerned, although perhaps to a lesser degree. The student learns to use a tool properly if he holds it properly and moves it properly. A student learns skill in drafting by holding his body, his arm, and his hand in correct positions while drawing. And, of course, he learns by actually doing it, not by reading about it.

5. Class concepts. As we have pointed out, the concepts which classify the environment are the basic stuff out of which education (as it is generally understood) is built. The student must learn a tremendous number of classifications of objects, things, and symbols. Any new subject-matter is full of class concepts to be learned--new instruments, new symbols, new formulas. The teacher's task in programming the learning situation has two major points of emphasis. On the one hand, the concept to be learned must be presented in a wide variety of stimulus contexts, in order to insure generalizability. If kinetic energy is the concept, for example, it must be made to classify not only the behavior of a physical object raised above the ground, but also the behavior of molecules of a gas, and the behavior of objects in magnetic fields. The teacher takes pains to insure that this conceptual response occurs in various stimulus contexts. On the other hand, there is also the task of differentiation, similar in essential aspects to that which arises in the learning of simpler activities. Confusion among class concepts must be reduced, just as confusion among identifications has to be reduced. Again, this appears to be a matter of arranging for "contrast" learning, in which correct concepts are reinforced, and incorrect ones not reinforced.

6. Concept sequences (rules and principles). Provided class concepts have been adequately learned, the task of education at this point is primarily one of providing the proper range and precision

of responses to go with these concepts. Basically, this is what is meant by giving concepts "meaning", or conveying understanding. To a considerable extent, concepts can be given meaning by verbal instruction. For example, mass, force, acceleration, can certainly be defined in words, and such principles are a part of what needs to be learned for genuine understanding. But apparently only a part. When used in rules, concepts must "make sense" to the student in terms of his own responses. This is the fundamental reason for demonstrations and laboratory exercises. Apparently, no amount of verbal instruction, and no amount of substituting numbers in formulas, can replace the actual performance of the acts of measuring the acceleration of a falling body. A meaning is conveyed by this set of operations which goes beyond mere words and symbols. Presumably, it is necessary to permit students to go through a set of overt activities, or at the very least to observe such activities, in order that they can then arouse the concept by themselves in a new situation. So there seems to be more than a scientific reason (the "operational" meaning of concepts) for carrying out laboratory demonstrations and exercises. Basically, this is one excellent way to insure that rules can be self-aroused, and that they control the individual's responses with sufficient range and precision.

Conditions of transfer. The idea of "teaching for transfer" has been emphasized for many years as a goal of education. This same idea is expressed in several ways. "Learning with understanding" is one. "Useful knowledge" is another. Let us try to summarize here the implications of the study of transfer of training for education.

First, we saw that the condition which appears to be of most importance in insuring transfer from a learning situation to a later performance (or learning) situation, is similarity. While this is a slippery term, we can deal with it to a considerable extent by speaking of likenesses in the two situations. What does this factor have to do with education? It means simply that the teacher's task is one of insuring that the situation to which the individual responds while learning must be like the one he is going to respond to eventually. Of course, there are superficial ways of bringing this about, as in using problems in arithmetic that being "George has five apples...", presumably so that the student will be able to transfer his arithmetic knowledge to an actual situation involving real apples. But we are trying to avoid this superficial meaning.

The sophisticated meaning of making the learning situation like the performance situation is to be found, again, by consideration of the kinds of human performances. If the individual must make identifications of objects in the performance situation, then it is identifications of these same objects which he should learn. Notice that this means that words for the objects are not the same as the objects, but merely symbols for them. (This is, of course, another reason for laboratory and practicum training.) On the other hand, if the individual is going to deal with class concepts in the final performance, let us not have him learn verbal sequences or something else instead. In other words, one can also make the learning situation unlike the performance situation by attempting to use "rote learning" for conceptual performance. In sum, the way to insure similarity as a basis for transfer of training is (a) to use the same kind of performance in the learning situation as in the task for which learning is desired; and (b) to arrange for likeness in the stimulus contexts of the two situations.

The mediation of behavior by concept sequences (rules and principles) is another factor of great importance to transfer of training. One of the most frequent findings of psychological research in this area is the dependability of high positive transfer when it is based on principles. In this case too the approach of the teacher who is planning the content of learning is to specify the kind of performance for which learning is desired. If the behavior is to be mediated by rules, then certainly one should teach these rules, and avoid trying to convey the material by means of inflexible memorized sequences. It may be noted in this connection that "teaching rules" is a matter of presenting the essential concepts in a variety of stimulus contexts, and with the use of the variety of responses required in the ultimate performance. A rule like "The product of the reciprocal of two numbers is equal to the reciprocal of their products" may be learned simply as a verbal sequence, in which case it is of little use to the student. What is needed instead is a learning situation which provides adequate practice in a variety of stimulus situations to which the class concept "reciprocal" applies, as well as the responses appropriate to "multiplying" in each of these situations. Again, the secret of learning a rule consists in practicing the use of the rule.

References

Here are some selected references which provide background material on human learning, the methods used to study it, and some of the experimental findings.

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PRINCIPLES OF LEARNING

W. K. LeBold

Purdue University

The purpose of this workshop is to provide a vehicle for applying some of the principles of learning to specific problems in engineering education. The case method has been selected and is presented in the material that follows.

Each participant will be assigned to one of five groups or committees. A Chairman and Recorder will be appointed to act as moderator and secretary for each committee. The chairman's duty will be primarily to keep the focus of attention on the problem assigned and within the general context of learning. The Recorder will attempt to keep a rough account of the chronology of topics discussed in the group meetings.

Each group will be expected to prepare a brief written report summarizing the discussion which includes recommendations relevant to the case and specific to the particular problem assigned to their group. This report will be presented by an individual selected by the group in a five minute oral report on Tuesday evening, August 29, 1960.

In addition, each participant should prepare for his personal use a list of educational practices in engineering which according to our present knowledge of human learning either facilitates or inhibits student learning.

Educational Crisis at State University

Dr. H. E. Sharp, 39, is Dean of Engineering at State University (SU), a state supported university in southwest US. Dean Sharp came to SU from NIT where he was Director of Research and Professor of Nuclear Engineering. During his five years at SU a number of important changes have been made, including the expansion of the graduate and research programs, substantial increases in faculty salaries, the addition of a number of outstanding engineers to the faculty, and the revision of a somewhat antiquated engineering curriculum.

Recently, Dean Sharp has been concerned about the effectiveness of the educational program. His concern has been precipitated by three somewhat independent reports. (1) The report of the ECPD accrediting committee,

(2) a student survey by the local chapter of Tau Beta Pi on educational practices, and (3) an institutional self-survey conducted under a grant furnished by the Fornige Foundation. The ECPD report while commending SU for the changes made since the last inspection noted that the classroom instruction observed during their visit was in general, poor. Dull lectures predominated with very little if any student participation. The ECPD report also was critical of other educational practices noting that homework assignments were rarely collected and when collected rarely returned.

In the Tau Beta Pi survey, students reported that quizzes and hourly examinations were rarely given; since in most courses the principal determinant of grades was the final examination, and as a result they tended to spend a minimal amount of time on their studies during the regular session, but crammed during the final exam period. The Tau Beta Pi report also revealed that a substantial proportion of the engineering students spent an inordinate amount of time on such activities as the Amateur Radio Club, intra-mural sports, television viewing, etc.

The institutional self-study report indicated that SU had a significantly better than average incoming student body on the basis of College Board Scores and high school rank when compared with other comparable engineering schools. The selective admissions program was due largely to the excellent State junior college system as well as the vigorous and active student recruitment program of the Registrar and Director of Admissions, I. M. Hunt. However, recent studies of the Graduate College and the Alumni Office indicated that State University engineering graduates did not perform too well in graduate work. In a nation wide study of engineering schools State University engineering seniors scored somewhat lower than the national senior average on both the Minnesota Engineering Analogies Test, and the Advanced Engineering Test of the Graduate Record Examination.

After discussing these reports with the engineering faculty at SU, it was generally agreed that the faculty, administration and students had not given sufficient attention to its intellectual and educational efforts. The faculty pledged their whole-hearted cooperation to Dean Sharp in his efforts to improve the educational program. It was generally agreed that Dr. Sharp should in cooperation with the Faculty Advisory Committee take immediate steps to improve the learning atmosphere at State University.

About this time, Dr. Sharp was asked to represent State University at an Invitational Conference on Educational Research in Higher Education.

At that conference he was impressed with the interesting and informative discussions of recent research on human learning. He was particularly fascinated with some of the experimental findings of an Eastern psychologist on "teaching machines."

When he returned to campus, Dean Sharp appointed a number of committees to work on various aspects of the general problem of learning in engineering. In appointing the committees he urged that each committee make a concerted effort to acquaint itself with the present status of knowledge regarding human learning and to utilize that knowledge in making recommendations which would optimize the learning atmosphere at State University.

The committees appointed and their specific assignments were as follows:

(1) Educational Policies Committee: Review present classroom teaching practices and make a series of recommendations which would improve student learning and facilitate retention.

(2) Engineering Curriculum: Review the engineering curriculum and identify the various kinds of human learning behavior which are normally expected of engineering students; cite general as well as specific examples of a variety of learning tasks including identification, motor sequences, verbal sequences, class concepts and concept sequences. (A la Gagne)

(3) Teaching Machines Committee: Select the general features of an individual teaching device based on the utilization of general principles of learning and make a schematic design of the device.

(4) Counselling Committee: Recommend a system of teaching, counselling and advising which will identify students with special talents or special handicaps; suggest methods by which gifted students can be developed and encouraged and assist students with special handicaps.

(5) Research Committee: Identify and design a specific study which will provide faculty members with useful and definitive information regarding the learning of engineering students and its relationship to current teaching practices.

In addition, each faculty member was asked to prepare a list of classroom practices in engineering education which according to contemporary learning theory tends to inhibit learning and to suggest practices which should facilitate learning.

"CONDUCTING CLASSES TO OPTIMIZE LEARNING"

Ralph W. Tyler
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INTRODUCTION

Teaching may be helpfully viewed in several different ways, but all of them recognize that (the purpose of teaching is to facilitate desired learning) on the part of students. For this reason, it is helpful to consider teaching activities, teaching problems, and teaching methods in terms of a broad perspective which includes the selection of what it is to be learned, how students learn, how student learning can be facilitated, and how the teacher may be guided in his efforts by finding out the extent to which students are actually learning what it is expected they would learn.

Conducting Classes to Optimize Learning

To provide an outline of a perspective of this sort, the following sections of publications I have written for other purposes are reproduced for this institute.

CURRICULUM CONSTRUCTION. First, we need to look at what is involved in the making of a curriculum.

The process of curriculum making involves four major steps. The first is to decide on the objectives which are to be sought through the curriculum. Explicit goals are necessary to guide learning because unguided educational experiences may produce a wide variety of effects, some more important, some less important; some desirable, some undesirable. In general, the term education is used to name a process that is concerned with changing the behavior of students, using behavior in the broad sense to include thinking, feeling, and acting. If a student is really educated at school, he will have ideas that he did not have before, knowledge that he did not previously possess, skills that had not been developed before, attitudes and interests that were not previously present. In brief, any educational process is concerned with bringing about certain changes in the way students behave. However, since there are many, many possible changes that could be made in students through educational activities and since the time of the school is limited so that only a few of the possibilities can be realized, it is very important that the particular changes that the school seeks to bring about are the most important changes which the school can produce so that no time is wasted on less important things to the neglect of those of greater significance. Furthermore, it is essential that these changes sought in students are clearly identified so that they will guide the work of the school.

The identification of the kinds of changes to be brought about in students through education is the process of formulating the objectives of the curriculum. The formulation of these objectives is ultimately a matter of choice; because objectives are consciously willed, they represent the purposes of the school. Although objectives are matters of value judgment, they are not wisely obtained by having individuals or committees make these judgments off the cuff or by accepting long standing practices without critical examination. The choice of objectives to be sought through the curriculum can be made much more wisely on the basis of several kinds of data.

In the first place, information about the students to be taught will suggest possible objectives. If the students lack certain important information, if they have not developed appropriate habits, if they are facing various sorts of problems and are having serious difficulties, if they lack breadth of interests, information about the present status of students will suggest possible objectives which the school might emphasize. Efforts could be taken to eliminate misinformation, to develop essential habits which are thus far lacking, to acquire knowledge and skills needed to solve important problems, to capitalize on the basic interests already in existence and to broaden and deepen them. These are simply examples of the fact that careful studies of the students themselves provide information which is helpful in deciding on the objectives of the curriculum.

Another important source for objectives is an investigation of the conditions and problems of contemporary life that indicate demands that society is making upon young people and adults and opportunities available to them. These demands and opportunities include the activities that they will be expected to perform, the problems that they will encounter, the difficulties that they will run up against, the opportunities for service and self-realization. It is easy to see that data on such matters help to suggest educational objectives of the school. Thus an analysis of our present life reveals clearly that the problem of war and peace is a problem of primary importance and one which every American citizen needs to understand more fully if he is to discharge his responsibilities of citizenship effectively. Such analyses made by curriculum makers have led many schools to give more attention to education for international understanding, to prepare units in international relations, to select a variety of instructional materials that deal with war and peace. Analyses of contemporary life have provided and continue to provide suggestions regarding important educational objectives.

A third source of suggestions for educational objectives comes from the deliberations of specialists in each of the subject matter fields who suggest what contributions they think their subject is able to make to the education of young people. Thus the reports of the several commissions on the social studies present the recommendations of specialists in this field regarding the objectives which they think social studies may and should attain in high school and college. There have been similar reports and recommendations from a number of other subject matter groups presenting their ideas as to the objectives which can properly be attained through instruction in these fields. Although these suggestions are in some cases not adequately supported by evidence that many students have actually reached such goals, they do, nevertheless, represent important possibilities which the curriculum makers must take into account. Hence this is a useful source of suggestions for objectives of the school curriculum.

The use of these three sources--studies of the student, investigations of contemporary life, reports of subject specialists--results in a list of possible objectives far greater than any school can possibly adopt. One of the reasons that formulating objectives is difficult is that there are many more things worth accomplishing in education than any school can possibly attain. Hence, it is necessary to make a careful selection of those aims which are most important, choosing only that number to which adequate emphasis can be given, and toward which the students can make significant progress. Since the curriculum builders are to select the most significant objectives among all these possible suggestions, it is not enough for the objectives to be worthwhile; they must be more important than those that have been omitted from the final list. In selecting from this comprehensive list of objectives the ones that shall be the primary goals of a curriculum, the educational and social philosophy of the school serves as a primary set of criteria. Each of the suggested objectives is checked against the school's view of "the good life for the individual in the good society" to see not only that no objectives are selected which are not in harmony with this view of the "good" but also to see that the objectives selected for major emphasis are those that stand high in importance in terms of this philosophy of education. For example, a school philosophy which holds that a good man in a good society will learn to make wise decisions, will be able to meet his own problems and to solve them through analysis and study rather than through blind obedience to authority, will give much greater importance to objectives involving skill in critical thinking, skill in analysing problems, problem-solving abilities, and the like. In this way the school's philosophy provides a major screen through which to sift a large number of objectives to select those of greatest worth.

A second screening is done by comparing the proposed list of objectives with what is known about the psychology of learning. This action is taken to eliminate those objectives which studies of learning indicate are not likely to be attained through school learning experiences, and to place at other levels those objectives which investigations of learning suggest are more efficiently reached at a different level of age or maturity. For example, to develop physiques that will eliminate susceptibility to the common cold is not an objective that can be attained through school learning. Hence, such a recommended goal would be eliminated. Furthermore, a senior high school list of objectives that placed emphasis upon emotional stability would be revised since learning studies indicate that this objective is more efficiently attained in early childhood and should not be postponed until adolescence. This step then of comparing possible objectives with the findings and recommendations of psychology of learning helps further to eliminate any inappropriate objectives and to retain those which are of basic importance in terms of the philosophy of the school and are attainable so far as we know from the present knowledge of learning.

The second step in curriculum construction is to select learning experiences that are likely to attain these objectives. The curriculum includes the learning experiences provided by the school, that is, the materials and methods of instruction, the learning activities of the student. These learning experiences are provided in a curriculum, when rationally built, as the means of attaining the objectives. Hence, learning experiences should be selected in terms of their probable usefulness in reaching the goals desired. This step in curriculum construction is largely guided by studies of learning which have been conducted both within the psychological laboratories and within schools. From these studies certain generalizations have emerged, some of which are tentative and others less so, regarding the conditions under which different types of student reactions are learned. The selection of learning experiences draws heavily upon these generalizations. Consider as an example a course in English Literature aiming at the following objectives: 1. ability to interpret literature with understanding, 2. appreciation of literary works, 3. skill in appraising the literary excellence of novels, 4. broad interest in reading literary works. The selection of learning experiences for such a course would mean to select experiences likely to contribute to one or more of these several objectives. This raises such questions as: What kinds of experiences are likely to develop increased ability to develop greater appreciation of literary works? What kinds of experiences are likely to develop skill in critical appraisal of novels? What kinds of learning experiences are likely to develop broad interest in reading literary works?

Answers to these questions in tentative form are drawn from psychological studies and from classroom experience. The reading of material that is already of interest to students or can be connected easily with their present interests, opportunities to analyze particular works to see more clearly the character and plot and the like, opportunities to compare several works to see the ways in which they differ and ultimately to derive criteria of criticism, opportunities to explore dramatic and significant literary material to derive satisfaction and appreciation, are kinds of learning experiences that previous studies suggest are likely to contribute to the attainment of these objectives. Experiences like these, then, are planned in developing the curriculum for such a course.

The third major task of curriculum construction is the organization of learning experiences so that the cumulative effect of the whole series of them will be as great as possible in attaining the objectives of the school. To a certain extent, education may be compared with water dripping upon a stone. Each individual drop appears to have no effect but over a long period of time the stone is worn away. Correspondingly each individual learning experience is not likely to show any marked effect, but if they are combined in such a fashion as to reinforce each other, they produce increasingly significant cumulative effects, with the result that profound changes and developments in the student may take place. The problem then of organization is how to arrange these learning experiences so as to get the maximum cumulative effect.

This concept of maximum cumulative effect can be defined in terms of three major criteria by which to judge the organization of learning experiences. The first is continuity, that major elements to be learned shall appear and reappear from day to day and month to month so that important objectives are iterated and reiterated. The second criterion is sequence, not only that these important elements to be learned shall be reiterated, but that each time they are taken up again, it shall be at a deeper and broader level that brings about sequential development rather than mere repetition. The third criterion of good organization is integration, namely, that the relationship among the various subjects in the school curriculum and between the school and out-of-school shall be such that many opportunities will be provided for reinforcement of elements to be learned from one field to another and between school and out-of-school activities. Thus the development of certain skills in arithmetic can be enhanced by providing opportunities in the shop, in science, in social studies or in other fields to apply some of these skills, and by using life outside of the school both as a basis for setting problems to attack in the arithmetic class and to provide opportunities to make further application of these arithmetic skills. It is obvious that integration as well as continuity and sequence are essential to obtaining the maximum accumulative effect from the various learning experiences of the curriculum.

The fourth major step in curriculum construction is evaluation. Up to this point the learning experiences and organizing principles used have been derived from previous practices and from general principles of learning. Because the curriculum is a complex aggregation of learning experiences planned for a variety of individual students, it is not possible to be sure in advance that a given unit, a given course, or a given program is actually producing the effects desired. It is therefore an essential part of curriculum construction to provide for periodic appraisal to determine to what extent objectives are being realized, where progress is being made and where it is not, and hence to provide a continuous evaluation of the effectiveness of the curriculum. Such an evaluation is essentially achievement testing, and unless it is carried on as a continuing part of curriculum construction, the curriculum is likely to misfire in certain respects and to go off in some unforeseen directions. By such evaluation, replanning and improvement of the curriculum become continuing phases of the curriculum building.

The foregoing section mentions four tasks included in planning a curriculum. These tasks are involved even in the planning of a single course, for in the single course objectives need to be selected, learning experiences worked out and organized, and evaluations made of the students' progress toward these objectives. Let us now look more closely at the clarification of the objectives for a course.

OBJECTIVES FOR A COURSE. The first difficulty a college teacher, or a college faculty, faces is to state the teaching objectives clearly enough in terms of the behaviors that the students are being helped to learn so that one knows what to look for in trying to find out how far the students have acquired these behaviors. Many statements which appear in college syllabi, course outlines, or catalogues are not statements of the things that students are expected to learn but are listings of content areas to be covered, or they are rather vague generalities such as to develop critical mindedness. A list of topics in a course does not indicate what the student is to learn to do with them and yet it is the student's behavior which becomes part of him and is his learning. Several teachers may deal with the same topics and yet the students might learn quite different things. Some teachers might want the student to memorize certain facts or definitions under these topics; some might want the students to acquire an ability to use certain concepts in analyzing the problems and issues in the field; some might expect students to be able to explain various phenomena by the use of relevant principles; and some might want the students to develop an interest in this subject that would carry on long after the course was finished. The mere list of topics does not indicate which of these or other kinds of behavior are being aimed at in the teaching. Until we are clear about what we are trying to help students learn, we have no beginning point for evaluation. Each of us needs to answer such questions as: What things am I really trying to get students to understand? What kinds of abilities and skills in thinking, analysis, problem-solving, and the like am I really trying to develop? What kinds of competence in reading, or writing, or mathematical operations am I actually seeking to help students to acquire? Am I trying to arouse certain intellectual and aesthetic interests, and if so, what are they? Am I trying to develop some study habits or practices that will aid the student in his continuing development, and, if so, what ones? Am I seeking to instill certain attitudes, appropriate to understanding or appreciation of phenomena in this field, and if so, what are they?

The teacher requires not only a list of student behaviors which he is seeking to develop but each kind of behavior must be clearly defined since the test of the clarity of the objective is whether one can recognize when students have acquired, or are acquiring, that objective. One often hears teachers saying that they are not aiming at factual memorization but are trying to develop understanding, but when asked what they mean by understanding and how it differs from mere memorization, many are unable to define or explain it. Some teachers do have in mind a fairly definite meaning for the term "understanding" by which they do distinguish it from rote memorization. They say that when students understand these concepts and principles, they can explain them in their own words, they can point out illustrations of them, they can recognize illustrations when they are brought to their attention, they can compare and contrast related concepts or principles, and they can use them in explaining or analyzing phenomena. Each of us might have a somewhat different defintion in mind for "understanding" but if we can define our objective in some such terms as these, we are able to use our definition as a basis for evaluation since we know what we are looking for when we try to find out how far our teaching has been effective in developing understanding. In similar fashion, we need to define every important objective toward which we direct our teaching. An excellent illustration of definitions of various commonly listed college objectives is found in a volume prepared by a group of college and university examiners and edited by Benjamin S. Bloom, called "The Taxonomy of Educational Objectives." This is the first of a series and it analyzes and defines objectives that involve primarily cognitive behavior. Later volumes are to be prepared which analyze other objectives such as interests, attitudes, habits and practices. These illustrations are useful in suggesting possible form and content for clarifying the meaning of objectives we are seeking in our college teaching.

When we have defined our objectives clearly by identifying the behavior sought in this way; we face the task of helping students to develop this desired behavior. In essence the problem is how to get students to carry on the behavior desired and to derive satisfaction from it so that the desired behavior becomes a more or less permanent part of the student's repertoire of behavior. Before answering this question by listing lectures to be given, laboratory projects to be assigned, papers to be written, and the like, it is helpful to think of the teacher's role as that of stimulating and guiding the desired learning both through his own exemplification of the behavior he is hoping his students will develop and through providing the conditions for effective learning within and without the classroom. For this purpose, the teacher may want to bring together for consideration and use what psychologists, other social scientists and educational practitioners have learned about the conditions under which effective learning takes place. In reviewing published materials one will find a number of lists of essential conditions but most of the lists have many common elements.

section

CONDITIONS FOR EFFECTIVE LEARNING. One necessary condition is student motivation. The learner learns what he is thinking, feeling or doing. Hence, learning is not possible except as the learner himself is involved in it. This makes his motivation, that is, the impelling force for his own active involvement, a very important condition.

A second condition for effective learning is that the learner finds his previous ways of reacting unsatisfactory so that he is stimulated to try new ways of reacting. As long as the learner does not recognize that earlier modes of behavior are inappropriate, he will keep on doing what he has been doing before and will not really learn anything new. Hence, it is necessary that the learner discover the inadequacy of his previous behavior so that he will not continue to repeat it. College students often carry over from their earlier school experiences the notion that study is memorization and when called upon to study in college courses, they try to memorize textbook materials. It is necessary for the college teacher to help the student discover that memorization is not a satisfactory means to solve the kinds of problems or do the sorts of exercises which the college class requires.

A third condition is for the learner to have some guidance of the new behavior which he tries in seeking to overcome the inadequacy of previous reactions. If he simply tries new behavior by trial and error, learning is very slow and he is often discouraged and gives up. Some means of indicating to him more promising reactions serve to guide him. Many ways are used to guide the learner in helping him to understand. Parts of syllabi, textbooks and manuals may be prepared or selected for this purpose. The instructor may ask questions which lead the student to look at various factors that he may have previously overlooked in his search for meaningful relationships. He may be aided in learning a skill by direct demonstration. These are only a few illustrations of the many common methods used in guiding behavior in learning.

A fourth condition for learning is for the learner to have appropriate materials to work on. If he is to learn to solve problems, he has to have problems to attempt to solve; if he is to gain skills, he must have tasks which give him opportunity to practice these skills; if he is to gain appreciation, he must have materials that he can listen to, see or respond to in other appreciative ways. When students have only the textbook and the classroom lectures, they do not have enough of the "stuff" for study, that is, the problems, the exercises and other materials to think about, to work on, to practice on to provide the necessary learning experiences.

A fifth condition for effective learning is for the learner to have time to carry on the behavior, to keep practicing it. This is usually referred to as "having study time." Often colleges assume that the student is spending time in study outside the classroom, when observation or interview will indicate that the student thinks that if he comes to class and spends a half hour or so outside, that is all that is required to learn. A more effective provision of study time is important for high-level learning to be reached. Studies of college students indicate that time which is presumed to be available for study is often occupied in commuting, outside work, extracurricular activities and social activities. Imaginative and realistic ways of providing study time can make a contribution to the effectiveness of teaching.

A sixth essential condition for learning is for the learner to get satisfaction from the desired behavior. As the learner interacts in the various learning situations, the reactions which give him satisfaction are continued; those which do not give satisfaction are dropped from his repertoire of behavior. If the learner wants very much to acquire a certain kind of behavior, such as understanding or a skill, the actual satisfaction of getting the understanding or skill is sufficient. On the other hand, teachers are in a position to help learners derive satisfaction from desired behavior when this satisfaction does not automatically follow progress in learning. For example, to become competent in a foreign language so that one can read stories or articles in that language takes a long time. In the interim, the teacher may exercise a considerable influence by complimenting the student on his efforts, by helping to get group approval of reasonable progress, by providing tests or other means for him to perceive that he is progressing toward his goal. These are but illustrations of the ways in which the teacher may increase the effectiveness of learning by helping to see that students get satisfaction as they make progress toward the desired goal.

A seventh essential condition for learning is opportunity for a good deal of sequential practice of the desired behavior. Sequential practice means that each subsequent practice goes more broadly or more deeply than the previous one. Sheer repetition is quickly boring to the learner and has little or no further effect. Only as each new practice requires him to give attention to it because of new elements in it does it serve adequately as a basis for effective learning. This is important for the student in gaining understanding because it means that concepts and principles are brought in again and again but each time in new and more complex illustrations so that the student continually has to think through the way in which these concepts or principles help to explain or to analyze the situation. It is important in the development of the skill to see to it that each new practice of the skill provide opportunities for greater variety or complexity in its use. It is also true in the development of appreciation, for it means that each new work of art should be demanding something more of perception and providing opportunity for a greater variety and depth of emotional response.

An eighth condition is for the learner to set high standards of performance for himself. One of the common difficulties of college is that the student may become satisfied with mediocre performance and no longer put forth effort to learn. This is a common problem with the more able student. It is often necessary to help the student to acquire standards of performance that for him are high but attainable and to lead him on continually to seek greater excellence. One may ask of any teaching program about the kinds of standards that the students are expected to meet and how far they are relevant to the individual differences among the students in the class.

The ninth and last of the conditions is related to the eighth, to continue learning beyond the time when a teacher is available, the learner must have means for judging his performance to be able to tell how well he is doing. Without them his standards are of no utility.

Other Factors in Learning. In seeking to establish appropriate conditions for learning in a college, an essential factor is the impression sensed by the students of what the most important values of the college community are. One college may clearly give students the impression that athletics is the major value, another college emphasizes social adjustment. The kind of educational objectives which the colleges today are likely to recognize as primary are those which require a different institutional atmosphere to support student learning. The attitudes of faculty, administration and older students should strongly indicate to new students that they are expected to "stretch their minds," to develop imagination, to acquire new ideas, new skills, new interests and the like. Learning is more important than social or athletic activities and it is more fun.

In planning systematically to make teaching effective it is necessary to recognize the different kinds of educational objectives sought, to define each objective clearly and to plan ways in which students can acquire each objective. This means that teachers need to distinguish between memorization and understanding, between knowledge and skills in problem-solving, between interests, values, attitudes and knowledge, vocabulary, skills. Furthermore, the teaching-learning situations must be planned so as to provide ways by which each student may carry on each of the kinds of behavior which are implied by the educational objectives. Too often we establish desirable objectives but the actual teaching-learning situations do not reflect some of these aims. The student cannot acquire a desired kind of behavior without having the opportunity to carry it on.

Students who come from backgrounds where few of their family or friends have been to college often require special consideration in developing appropriate motivation for college work and opportunities for practicing the desired behavior outside the classroom. This may require teachers to plan learning experiences for such students in which a good deal of concrete learning precedes generalization. It may require the development of special learning tasks which these students can do well, for this successful experience will encourage their further efforts in learning. It may also require learning exercises in which the meaning and practical value of conceptualization and generalization are spelled out because these students have often heard ridicule aimed at "theorizing" and they have had limited experience in using what they could clearly recognize as theoretical notions.

In large colleges and universities, the student groups often serve to influence the learning of the members. Some groups re-enforce the efforts of the college, some insulate its members from the influence of faculty and administration, and some groups are in rebellion resisting college efforts. The engineering college is often small enough to develop working groups that include students, faculty and other adults in the community and in this way help to make learning more effective.

Where there is a close relation of the college to the community it is possible to conduct some learning outside the classroom under the stimulus and guidance of persons in community situations who are not college faculty members. This outside arena for learning can serve as an important re-enforcement for the college and should be used when effective learning conditions can be provided for one or more of the educational objectives of the college.

In the development of values, students are strongly influenced toward the values accepted and cherished by persons they know and admire, particularly by persons with whom they can identify. Discussion, analysis, and explanation may serve to clarify the meanings of values and their rational bases, but commitment to values on the part of youth and adults is more largely influenced by experiencing the satisfactions that come from commitment and by vicarious experience with these values through identification with persons exemplifying them.

Relatively informal and direct personal relations in the college provide a favorable setting for the development of values if the values of the admired persons in the situation are clearly and well exemplified. A college has a special opportunity through its faculty, young adult leaders and collaborators to contribute to this important learning process.

THE ENGINEERING TEACHER SPEAKS

Wesley Wiksell
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Speaking is the essential[1] part of your teaching when you:

1. Lecture in the classroom or over television
2. Introduce and conduct a discussion to be shown on film, filmstrip, slides, or television broadcasts
3. Explain objects, models, or charts
4. Explain assignments
5. Answer and ask questions to determine the students' understanding of a problem
6. Amplify, interpret, or adapt a point of view in the text

According to a survey given to 150 engineering students, effective engineering teachers speak in a logical and well-organized manner rather than a rambling and disorganized one. They clearly indicate the central points and adequately support them with illustrations and examples.

They use language the student can understand.

The effective engineering teachers' deliveries are direct, confident, lively, friendly, and conversational and are accompanied by appropriate actions of the body, arms, and head yet free from distracting movements. Seventy per cent of the students indicated the worst engineering teachers they ever had read notes or text or faced the blackboard most of the time.

The good instructor's speech is distinct. Sixty-five per cent of the students wanted their instructors to speak more distinctly.

They speak loudly enough to be heard easily. Fifty-nine per cent of the students said their instructors did not speak loudly enough. Many students specifically commented that the instructors talked so softly they could not be heard. The effective teachers can be heard easily.

The best engineering teachers are sensitive to good physical arrangements in the teaching situation.

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[1] This does not mean that verbal communication is the only way to transmit information. The engineering teacher should always consider every medium of communication at his disposal before selecting the best ones. He should use the written word, the picture, or the object as often as he can.

Frequently, however, engineering teachers reflect these points of view toward the manner in which they present their material.

1. "Well, after all, it isn't important how I speak. I know the subject matter and that's what counts. It is the student's responsibility to get the message regardless of how I say it." Thus the teacher often sounds dull, academic, or inarticulate.

The surveys answered by students indicate they want good speech on the part of the instructor. Students have little patience with a halting, garbled manner of speaking.

2. "I sound all right. I can hear myself speak."

One only thinks he hears himself as his students hear him and that his speech improves with practice. True, an instructor does hear himself, but not as his students hear him. If he decides to change his speech, he does not know what to change. Practice does not insure improvement. Real improvement in speech is difficult; repetition of bad habits only leads to a permanent host of bad habits.

3. "Some teachers are born lecturers. There is little I can do to improve my speech."

Yes, some teachers do speak well without any training just as some singers, athletes, and architects do well without training. But anyone can improve, and countless teachers have improved themselves through training.

4. "Speech should be natural. Training would make me unnatural or artificial in manner. My speech should be slow, ponderous, and halting, if I feel that way."

In reality, training should help the teacher to speak in a manner that is in harmony with the material presented and the audience addressed.

5. "If I take steps to change my speech, I can improve overnight. Six easy lessons will do it, and once improved, there is little regression."

True, improvement can be seen from training, but the process is long and often difficult. An effective skill in speaking is harder to acquire than most people think.

Suggested Course of Action

1. Recognize the importance of speech in your work as a teacher. Without this positive attitude, in all probability, you will do very little toward improvement.
2. Ask all of your students to answer the following Inventory of Factors Involved in Speaking. Follow the recommended procedures for giving opinion surveys described in the chapter on evaluation procedures to be sure you get frank answers.

Inventory of Factors Involved in Speaking

Below is a list of suggestions for your teacher. Check those you think he should follow to improve his teaching. Do not sign your name.

The teacher in this class should:

	Yes	No	Comments
(1) State the main point more clearly when he talks			
(2) Give more examples and illustrations to clarify his main points			
(3) Explain his assignments more clearly and understandably			
(4) Discuss and explain his visual aids more carefully			
(5) Use more humor			
(6) Use less humor			
(7) Use fewer unfamiliar words			
(8) Use a more conversational language			
(9) Speak in a more confident, friendly, and pleasant manner (Please explain)			
(10) Speak more rapidly			
(11) Speak more slowly			
(12) Eliminate jerkiness in speaking			
(13) Vary his rate of speaking			
(14) Reduce the monotony of speaking on the same pitch level			
(15) Eliminate a rising or falling pitch pattern			
(16) Speak more loudly			
(17) Speak more softly			

(18) Vary the loudness of his speech

(19) Avoid mumbling words

(20) Avoid speaking in a breathy, husky, or hoarse manner

(21) Eliminate annoying or distracting movements or mannerisms when speaking (Please explain)

(22) Have more class discussion and questions

(23) Give attention to physical conditions (such as use of light, heat, ventilation, visual aids)

Other comments:

3. Study the responses. Many of the comments will puzzle and alarm you. Discuss some of the points with a few of your students and colleagues to get their interpretation.
4. Make a recording and a tape of everything you say from the moment your class begins until it is dismissed. Do this several times. Study the recordings and check the reactions of your students on the Inventory which you have.
5. Ask two or three of your fellow teachers to rate you on the Inventory of Factors Involved in Speaking.
6. Ask a member of your Speech department to visit one of your classes and evaluate you on the Inventory of Factors Involved in Speaking.
7. Get any individualized speech training recommended by him.
8. Have a reappraisal by the speech instructor once a year. Speaking habits change over the years, and progress can be seen only through such an evaluation.
9. Enroll in a speech course in your university. Or ask the speech department to set up an extra non-credit course for the teachers at your university, such as the great one given at the University of Michigan some years ago or similar to the one conducted at the University of Hawaii on methods to stimulate class participation. This course was given from 4 to 6 P. M. every Monday afternoon for six weeks.

10. Take every opportunity to speak in your service club, church, or civic organization. Accept responsibilities that lead to opportunities to talk to groups.
11. Study the following material on speaking and then follow those suggestions that apply to your needs as indicated by the students' responses, your recordings, and your speech instructor's findings.

Initial Suggestions to Make Anything you Talk about Easier to Follow:

Do not lecture if there is a better way to present the material. If it is not necessary to elaborate on information that is in written form, do not lecture about it. Students complain about the instructors who add nothing new to the text or read the assigned material in great detail. If a demonstration will do a better job, you should not lecture about it.

Do not lecture for an entire period without using visual aids. Use as many visual aids as you can to help you in your presentation. Learning is easier when sight is combined with hearing than by hearing alone.

The most important reasons for appearing before your students are: to stimulate their interest (so far, there is no substitute for the personality of a professor to make a subject interesting); to explain the subject in greater detail; to catch misunderstandings, doubts, and differences in learning rate; and to see progress in students. Consequently, your chief point of attention should be the student. Is he learning from what you say? Is he learning from the textual material, the visual material, or the test he has taken? You must organize your material with these considerations so you can tell if he understands what you say.

Specific Suggestions for Improvement

If your students indicated the need to:

-State the main point more clearly when you talk.

-Give more examples and illustrations to clarity your main points.

-Explain assignments more clearly and understandably.

-Discuss and explain visual aids more carefully

Present your outline of the lecture early. You might have the outline mimeographed or written on the board. A book does this by means of a table of contents. This structure might be something like the following when presenting scientific material.

1. Relate your contribution to previous lectures, readings, or work
2. Present the main idea. This would be your conclusion, your findings, or the most important point in your lecture.
3. Explain how the conclusion was reached.
4. Consider obstacles, problems, difficulties.
5. State significance, possibilities, speculations, or weaknesses.

If you are answering a question, use every device you can to show time sequence, such as "First, we will. . ." and "Second, we will. . . ."

Master the use of transitions to show relationships, such as:

"On the other hand..."
"Now, then..."
"Here's a case of..."
"We've really said nothing about..."
"The most important aspects of these seem to be..."
"When a second..."
"What is a ________? Well, in this case it is...."
"The answer is..."
"What we really mean..."
"When you read further..."
"This is one reason chemists are so excited..."
"I'd like to make..."
"Actually..."
"For example..."
"Let's go back to..."
"What do those look like?"
"It's quite unusual..."
"The important point is..."
"Lastly..."
"The usual way..."
"Another one..."
"The example I spoke of..."
"Perhaps more interesting than any of these..."
"But more interesting than these..."
"Now, this is a complex principle..."

"For contrast, let me just point out..."

"What I'm trying to point out..."

"Let's take an observation..."

"Let's just watch and see what happens..."

"The light is on now...it's getting dimmer and dimmer and dimmer and dimmer..and now it's gone out..."

"That's our mystery for next time..."

Choose only the information and ideas that will make the main point clearer to the student. If the item has no real meaning to the student, strike it out. Brevity is not only important in the use of words but also in the amount of material to be conveyed. Most people tell too much at one time, even in teaching.

Illustrate profusely. It is easy to go too fast in discussing generalizations.

Make your examples as concrete as possible.

These illustrations, anecdotes, specific instances, and practical applications can come from your experience with students, industrial situations, colleagues, former professors, readings, periodicals, or newspapers. They reveal you as a human being and not only make what you say remembered longer but also result in a greater understanding of the generalizations being studied.

1. Record your lectures before you give them. Listening to the tapes will show where you do not make yourself clear or where you dwell on a point too long. In addition, it is a pleasant way to practice aloud.
2. As you listen to a lecture you have given, outline it as you think your students would.
3. Listen to the instructions you gave. Were steps omitted? Did you emphasize the principal parts sufficiently?

If your students indicated the need to:

-Use more or less humor.

Humor has an appeal to students. It is essential in a good teacher, but sometimes over exercised. Most students enjoy jokes but not vulgarity, obscenity, or horseplay.

A good instructor does not plunge into his subject immediately. At the beginning of the hour, he makes a few general remarks or tells a story to attract the attention of the class and focus attention on the subject. If your students think you should use more humor, try it. Go out of your way to look for jokes related to the material discussed. Practice the stories and jokes on your recorder. Professional speakers do.

Language

If your students indicated the need to:

-Use fewer unfamiliar words

-Use a more conversational language

In general, instructors use more elaborate words and phrases than necessary. But, long words often make both the teacher and the subject under discussion appear difficult and ponderous. Instead of making the subject easy for the student to understand, they confuse him. Willard Bennet warned communication teachers that (the engineer) "...is inclined to wrap his thoughts in a soggy cloak of terminology."[2]

1. Make a list of the technical words you used. Ask yourself if your class understood them. Could other words, less difficult to understand, have been substituted?
2. Give short tests from time to time to see how well your students understand the technical words you use.
3. Periodically ask your students to define the terms you use.
4. Give the students a list of words that you will use in the period, with their definitions.
5. Use the shorter alternatives to the long words and phrases you find here:

   Accordingly---------------------for---------------And so
   Accumulate----------------------for---------------Gather
   Acquaint------------------------for---------------Tell
   Additional----------------------for---------------Added
   Afford an opportunity for-------for---------------Allow
   Anticipate----------------------for---------------Forsee
   Apparent------------------------for---------------Clear

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[2] Willard E. Bennett, The Need for Effective Speech in a Technological Society, Southern Speech Journal, Vol. 17, p. 38, Sept. 3, 1951.

Approximately	for	About
Assistance	for	Help
Commence	for	Begin or start
Commitment	for	Promise
Compensation	for	Pay
Complete	for	Finish
Contribute	for	Give
Construct	for	Build
Demonstrate	for	Show
Depart	for	Leave
Desire	for	Wish
Endeavor	for	Try
Equivalent	for	Equal or same
Expedite	for	Hurry
Facilitate	for	Make easy
Feasible	for	Possible
Ill or Indisposed	for	Sick
Inasmuch as	for	Since
Initial	for	First
In most instances	for	Usually
Initiate	for	Begin or start
In several cases	for	Often
Is an indication of	for	Shows
Reside	for	Live
Subsequent	for	Next
Sufficient	for	Enough
Terminate	for	End
Utilize	for	Use
Voluminous	for	Bulky
Was made a recipient of	for	Was presented with or was given[3]

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[3] Wesley Wiksell, *Do They Understand You?*, The Macmillan Company, New York, 1960, pp. 68-69.

Voice

If your students indicated the need to:

-Speak in a more confident, friendly, and pleasant manner.

The engineering professor's voice is one of the most important tools at his disposal.

Your ideas are transmitted as words with your voice. Through your voice, you also indicate whether you are bored, tired, irritated, impatient, indifferent, or friendly as you lecture, explain, or disagree with the student. This is particularly true when you are under stress. At that moment, you may unwittingly convey a spirit of anger, dislike, or irritation with your voice, far from the impression you intended. However, the students do not ask for reasons or motives. They interpret the communication as it takes place at the moment, reflecting the negative attitude toward the subject or toward them. The students become irritated and lead to resentment, discouragement, and often failure.

On the other hand, a warm, confident, friendly, pleasant voice arouses a positive response. The students are more likely to feel they understand the instructor and to want to work.

1. Listen for sarcasm, fatigue, bluntness, impatience, and other undesirable traits of speaking on your tape recording. Change your "tone language" in succeeding lectures and check your recordings for improvement. If this becomes a habit you can overcome many of these faults.
2. If speaking unpleasantly is not a habit, you may have an attitude of dislike, prejudice, and impatience with students that should be changed through careful self-analysis; study the chapter on self-confidence in Public Speaking: Principles and Practices.[4]
3. You may be tired from poor health, overwork, or worry. A doctor may be able to help you.

If your students indicated you need to:

-Speak more rapidly

-Speak more slowly

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[4] Giles Wilkeson Gray and Waldo W. Braden, Public Speaking: Principles and Practice, Harper & Brothers, New York, 1951, Chapter 5.

-Eliminate jerkiness

-Vary your rate of speaking

The students who were surveyed stated that the engineering teachers often talk too slowly. If you talk too slowly, the student, who can listen much faster than you utter your words, becomes bored or distracted, and his mind wanders. On the other hand, if you talk too rapidly, you are likely to slur your words so he is unable to understand them. Ordinarily, one should speak about 140 to 160 words a minute. However, do not take this too literally. There is no one rate of speaking that should be used at all times. The type of material you are talking about, your use of teaching aids, the size of the room, the acoustics of the room, the size of the class, the difficulty of the material, or how well you, yourself pronounce words are determining factors. In the latter case, some people can talk much faster than others and still be understood.

The lecturer who speaks too rapidly commonly makes the duration of the words and syllables too short. When he tries to speak at a slower rate, he continues to keep the duration of his tones short, but lengthens the pauses between his words. Conversely, the lecturer who wants to speed up his rate often shortens the pause between words, and retains the lengthened tones. Watch for this.

A second aspect of rate, as with the other factors of voice, is variety. A steady rate of speech becomes deadly to the listener. Talk slower at times, then talk faster, depending on the difficulty of the material.

Be sure to pause long enough between ideas. If you talk rapidly, be careful not to turn away from the class when you give key ideas or words. When you talk rapidly, you will also find it harder to get variety in pitch or force.

1. Practice speaking faster or slower over the tape recorder depending on your needs. Count the words to see if you speak between 140 and 150 words per minute. When you listen to your tape see if you pause too often or not enough. You are pausing too often if you pause after every two or three words. On the other hand, you may speak two or three sentences without a pause, thereby making it difficult for students to follow you.
2. Study your recording to see what you do when you pause between words or sentences. Do you have the "uh" habit? This results from not being sure of what to say next and trying to bridge

the gap with sound. It is extremely annoying to your students. Frequent listening to your tapes will help you eliminate this bad habit.

3. Ask your students if you are talking too rapidly or too slowly.

If your students indicated the need to:

-Reduce the monotony of speaking on the same pitch level

-Eliminate a rising or falling pitch pattern

The "highness" or "lowness" of your voice is referred to as pitch. The normal voice should have a medium pitch, low rather than high. A high pitch in a man's voice, which is often unpleasant, may be emotional or glandular, and the advice of a physician should be sought when this has been discovered from your recording or instruction.

A voice that is pitched too low is generally weak, breathy, and inflexible. It often results from habit. The lecturer who drones along at the same tone level all of the time, without raising or lowering his voice, is monotonous and lulls his students to sleep unless they stir themselves to keep awake. Actually, the lecturer can change his pitch about two octaves. Within this range, the competent speaker causes the pitch level to rise and fall depending on the material he is discussing. But because pitch depends on the tension of your vocal cords which cannot be controlled consciously you can only experiment or work with a teacher on raising and lowering the pitch of your voice.

1. Listen to the recordings of your lecture. Ask yourself if it lacks variety. Wide variations in pitch are more likely in animated, lively communication than intellectual presentation. This does not mean, however, that you should not have variety in pitch when discussing technical information. Pitch changes should be evident when you ask for or give information, are doubtful or certain, or are making asides. You will notice that the pitch changes may be a leap or an inflection. You should use both to get interest and to make fine and delicate distinctions between ideas.
2. Practice making explanations over the tape recorder. If you do not progress, talk with your speech instructor about it. This may require more professional insight than the layman can give.
3. Practice parts of your lectures aloud. Through raising the pitch, emphasize the main points so a student can get them easily.

4. Practice reading poetry with an emphasis on variety in pitch. Exaggerate changes in pitch.

If your students indicate the need to:

-Speak more loudly

-Speak more softly

-Vary the loudness in your speech

The volume and quality of your voice depend on the energy you put into your speech and the shape and use of your resonance chambers. The volume you use is of great importance. You have a responsibility to be heard. If you do not speak loudly enough to be understood by your students you might as well be talking in a foreign language or not at all. Students become bored, misunderstand, or fail to get what you say if they cannot hear you easily. This is a common complaint they make.

A strong voice is usually clear and pleasant. The terms "breath," "hoarse," or "nasal" refer to quality. You might change the quality of your voice to a degree if you feel the need for a change. However, such a change is unlikely. You cannot do much about it without expert instruction, and even then it is extremely difficult.

1. Listen to your recording again. If you are talking too softly, you can raise your volume by giving it more energy. But do not be misled. It is easy to raise the volume control of the tape recorder, you understand what you said, and you are likely to stand close to the recorder when speaking. Your students were not that close to you. What about the student who was sitting 20 or 30 feet away?
2. When talking, ask your students if they can hear you. Generally, they will indicate that they are unable to hear you.
3. Adapt the volume of your voice to the size of the room in which you are speaking. If the room is small you can and should speak with less volume than in a larger room or one with a high ceiling. However, you should talk louder than you ordinarily do in conversation because you are farther from your students and a group of people in a room absorbs the sound.
4. Adapt the volume of your voice to the material you are discussing.

Variety is important here, too. Because of their importance, some words or points in your material should be stressed with more volume. Read the following sentences, accenting only the underscored words in each. The changes in meaning are obvious

What did you say?
What did you say?
What did you say?
What did you say?

5. Talk louder when you are using visual aids. This point will be mentioned elsewhere in this chapter.
6. Become sensitive to distracting influences. If a car passes the building in which you are speaking, a bell rings, or students pass down the hallway talking loudly, it is your responsibility to increase your volume to overcome the disturbance or stop talking until it has ended.
7. If you are talking to classes of 40 or more students, you should use a microphone. It is easier for everyone to hear you, takes less effort on your part, and allows you to be more conversational and get greater variety in your speech. You can whisper some words or say others with considerable force. If you try to teach in a large auditorium without an amplifying system, you are likely to speak at the top of your voice all the time. Then, you cannot speak any louder if necessary, or if you talk lower, you cannot be heard. Your lecture becomes monotonous. A lavaliere microphone is best for this purpose. A stand type of microphone has many disadvantages because it restricts your movements and makes it practically impossible to use visual aids of any kind. With the portable microphone, you can hang the string around your nect and forget about it. However, as indicated before, be sensitive to the quality of the tone (keep it set on average between tenor and bass) and the volume. Someone in the room should check the volume at intervals. If it is too high, distortion occurs.

Of course, it takes more time, money, and effort to use an amplifier. As with many mechanical aids, thére are times when it will not operate properly and your patience will be strained to the utmost.

If your students indicate the need to:

-Avoid mumbling your words

-Avoid speaking in a breathy, husky, or hoarse manner.

Even though you may speak loud enough, students may not understand because you mumble your words. The spoken word cannot be swallowed or uttered in a colorless manner. Many words sound alike. If you say nine and your students hear five they will blame you for misunderstandings. Because many words sound alike, this kind of thing can happen frequently. For example, here are some words that sound alike.

fifth -- sixth
seven -- eleven
clips -- chips
oil -- foil
tank -- plank

1. Listen to your tape recording to find instances where you slur your words. Then, practice articulating them accurately.
2. Speak more slowly and articulate important or difficult words with greater energy. Expend more energy on consonants than you usually do. You might even spell important words or write them on the board.
3. Never speak with a pen, pencil, cigarette, cigar, pipe, or gum in your mouth. Such objects not only interfere with clear speech but are annoying to students.
4. If you are not improving satisfactorily, follow the program suggested by your speech instructor. If he cannot help you, you may need an examination by a speech pathologist or physician.
5. If your students indicated you need to avoid speaking in a breathy, husky, or hoarse manner, see your doctor today!

Bodily Action

If your students indicated the need to:

-Eliminate annoying or distracting mannerisms

As with all other aspects of delivering lectures, there is no one way to use your body. Some instructors move a great deal, others move very little.

It is possible to generalize to this extent: It is easier to watch something move in a variety of ways than to watch something that doesn't move at all, but it is monotonous to watch the same movement again and again.

According to the findings of a study by Barr, the "poor teacher never stood while the good teachers stood most of the period. The good teacher stood in front of the desk. No good teacher sat for an entire period; poor teachers did... Good teachers are more inclined to move about and to lean upon furniture than poor teachers... Good teachers, however, showed marked superiority in physical vigor and in emphasis upon energy, vitality, and alertness as a prerequisite of teaching success."[5]

As a lecturer you should be seen clearly but what you do, whether good or bad, should not be in bad taste or detract the attention of your students from what you are saying. If you do, you are performing, and this distracts from your message. Everything you do should contribute to the expression of your message. As with your voice, your entire body expresses fatigue, energy, or disinterest. But, this does not mean there should be no bodily activity. Proper bodily activity is absolutely necessary to reinforce your message and to handle the objects necessary in your demonstrations. Without it the listener finds it difficult to listen.

How can you improve bodily activity? First, you should feel the urge to use your hands and body as well as your voice as a reflection of your energetic well being. This is opposed to a feeling of apathy or an "I don't care how I talk or sound, you can take it or leave it" attitude.

Second, the factor of energy, as every other factor of lecturing, is valueless if it is not perfectly regulated or controlled. You should not show off with a great display of energy by bounding up to the platform, constantly swinging your arms about, shoving your hands in your pockets, rubbing your face and arms, or running your hands through your hair. The cure for such aimless and distracting action is to indulge in no action that is not necessary to get something done or to express some meaning. This requires a careful self-analysis to detect any mannerisms that detract from your lecture. Some of the most common are:

Stroking the face
Rubbing one's hands
Shoving hands in pockets
Throwing chin up and out as though collar is too tight

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[5] A. S. Barr, Characteristic Differences in the Teaching Performance of Good and Poor Teachers of the Social Studies, Public School Publishing Company, Bloomington, Illinois, 1929, p. 73.

Hanging one's head
Putting weight on one foot
Rocking back and forth on heels and toes
Rising on toes at intervals
Throwing chalk up and down
Waving a pointer
Glancing from side to side
Putting glasses on and off and twirling them for no reason

Self-control does not mean a deliberate study of every movement, such as thinking, "Now I should lift my right hand." This would be worse than turning all of your energies loose to take their own course. Instead, be sensitive to aimless and useless actions, and force yourself to co-ordinate your movements with the message at hand. At first, you will feel awkward, but with continued attention to these problems, you will notice a gradual improvement.

When should a person move? You can move as much as you wish as long as you do not move the same way all of the time. You can move from side to side of the room. You can lean against a table or lectern. You can sit on the table, as long as you do not sit there all of the time. A general rule, however, is to move at the transitions of your talk. In other words, if there is a change in content, there should be a change in bodily movement. If the change is slight, such as different ideas in a paragraph, the movement should be correspondingly slight. It might be a shift of the head from one side of the class to the other. However, if you have concluded a phase of your talk and are about to begin an entirely new phase you might take three of four steps. But, when you take these steps, keep your eyes on the class. If this is done casually, the class is not aware of a movement, only that you are beginning a new phase in your lecture.

Gesture, facial expressions, movements of the neck and shoulders, the arms and hands, and the torso are closely related to movement.

Use your hands to show size, shape, direction, or capacity. There is no pattern, plan, or rule for gesturing. Generally, you cannot gesture too much. But, use your hands in a spontaneous manner, not jerky, nervous movements that mean nothing and distract from your effectiveness. This should be almost an unconscious gesture, not taught, not planned, not learned, but a reflection of what you are saying.

Be careful when handling notes written on thin sheets of paper. It is natural for the hands to trembly slightly, causing the papers to shake in an exaggerated manner.

When using a pointer, point directly at the object. Instructors often permit it to move over a wide area or play with it with their hands when they use it. It is even worse when they use a spotlight in a darkened auditorium. The light strays from the material being talked about and hits the floor or the ceiling. Rest the pointer on the lectern when you use it, and preferably, have it aimed before you turn it on. Follow the diagram on the screen carefully. Do not keep the pointer on the object after you discussed it and turn the spotlight off before you begin to discuss some other aspect of the problem. Be sure you are talking about the part you are pointing at. When using objects, hold them in front of you, but put them away after you have shown them. If you can avoid it, do not have them in view before you use them.

Nobody likes a sphinx. Even though the material you are talking about is objective and not of an emotional nature, you are still talking to human beings who have feelings and likes or dislikes. So, smile! Show enthusiasm and friendliness. Smile, frown, or even sneer at the material if the content lends itself to it. Laugh once in a while. Barr notes that: "Many more good teachers laughed with the class about various incidents than did poor teachers. Good teachers were much more inclined to smile appreciatively than poor teachers."[6] According to student surveys, good teachers are more inclined to gesture, to nod to students, to ask questions, to point to students to recite, and to nod approval.

Bad eye contact distracts even more seriously from effective presentation than other more obvious bodily actions. Maintain audience contact throughout your presentations. Address your remarks directly to the class. Watch every student in the classroom. Some bad habits to watch for are:

Squinting
Looking above the heads of the class
Looking out of the windows or to the side of the classroom
Looking at the ceiling
Closing one's eyes
Looking at the class but not seeing it

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[6] Ibid, P. 73

Looking constantly at one's notes or text

Constantly looking at the blackboard, object, or visual aid

Shooting the eyes rapidly from one side of the room to the other, resulting in a quick movement of the head

Fixing one's attention to one spot

Looking at no one in the class

Students are critical of the instructors who read long tracts, or entire lectures, or refer to their notes too often. Some authorities maintain that one should never refer to notes. They say that the use of notes creates a barrier in communication because the lecturer's attention is focused on the material in front of him rather than on the students; encourages inadequate preparation, because notes take the place of practice; and restricts him in the use of visual aids because he must either stay glued to his notes or wave them before the class with one hand while trying to handle chalk, signs, or a projector with his other hand. Students often lose confidence in the instructor. After all, if he cannot remember 5 points, why should he expect the class to remember them?

On the other hand, when properly used, notes have these advantages:

First, they contribute to the poise and self-assurance of the instructor. Even a veteran professor can become unnerved when faced with a hundred engineering students and 50 minutes to lecture without carefully planned notes.

Second, under the stress of talking for an hour, ideas may be forgotten or given in the wrong order. Notes would help.

Finally, supporting evidence such as facts, statistics, or quotations can be used more easily with notes. It is unreasonable to expect the instructor to memorize specific details that he would not ordinarily use in his work.

The following on the use of notes should help you to use them effectively:

1. Notes should be on cards. This will make them inconspicuous. Large sheets of paper attract attention, shake whether the lecturer is nervous or not, and are hard to keep in order.
2. Keep your notes concise. A few key words, statistics, or a quotation should be enough.
3. Type or print your notes and underline the key ideas.
4. Use only one side of the cards.
5. Number each card so they can easily be kept in proper order.
6. Do not refer to your notes any more than you have to.

7. Make a notation at the bottom of each card to help you anticipate the next idea.

Suggestions to help improve bodily actions:

1. Have your speech instructor study your actions when you talk. Follow his recommendations.
2. Have a photographer take a series of pictures of you while you are talking. Study the pictures, and take the necessary course of action.
3. Have a video tape made while you give an explanation.
4. Watch yourself in your mirror as you practice part of your lecture.
5. Confer with your doctor if you feel tired or listless.
6. Have someone watch you practice and stop you when your eyes are not directed towards the class or the objects you are discussing. Repeat the material where you did not use good eye contact, this time being sure to look at the persons watching you.
7. Force yourself to concentrate on every student in your classroom. Think about their reactions. Watch for sleepiness, lack of attention, boredom, or bewilderment. Some instructord do not even see the clock on the wall. Some do not notice outside disturbances and their effects on the class.
8. Plan your comments so you can expect certain reactions at certain places, such as contributions, questions, or laughter.
9. As you talk, watch for bewildered expressions, reluctance to do work quickly, or other cues that indicate a failure to understand.
10. Refer to students in this class. Look at Joe Smith at one time and refer to him. A little later do the same thing with Fred Jones. This has been done for years in the small classes but seldom in large engineering classes. Effective lecturers have learned this lesson.
11. A member of the physics faculty at the University of Michigan has adapted for experimental classroom use a device widely used for recording votes in legislatures. Each student has, at his fingertips and out of sight of the other two students two buttons, one to indicate a "Yes" and the other a "No" answer to a question raised by the lecturer. After sufficient time has been given, the lecturer pushes a control button that records the individual answers permanently and also flashes the individual answers to the whole class on a column of red and blue lights.

Getting Class Participation

If your students indicate the need to:

Encourage more class discussion and questions

Use questions to stimulate interest, encourage student participation, clarify understanding, spot-check the effectiveness of your teaching, maintain attention, or review material. Your purpose is to stimulate the student's thinking rather than to test his knowledge. The following suggestions should help you improve your technique:

1. Limiting questions to a single item.
2. Direct questions to the nature of the entire class first.
3. Use questions beginning with why, what, when, how.
4. Phrase questions so they do not suggest the answer.
5. Avoid "trick" or "catch questions.
6. Formulate questions by using the following words:

Analyze
Calculate
Clarify
Compare
Construct
Contrast
Criticize
Describe
Develop
Estimate
Evaluate
Explain
Figure
Give
Give the answer

Highlight
Indicate
Justify
List in order
Make
Outline
Point out
Select
Show the relationship
Sketch
Tell
Trace
Work out
State in sequence

Make it easy for your students to ask you questions at any time during your class. Be a good listener.

1. Show a friendly attitude to encourage students to ask you questions.
2. Be sincere in showing you like to get questions from your students.
3. Make the student feel he is on an equal basis when discussing problems or ideas.
4. Receive loaded questions as objectively as objective ones.
5. Show friendly inquiry if a student submits information you do not understand.

6. Encourage the student to develop or explain his ideas further rather than interrupting him when he talks.
7. When a student asks you a question, give him your undivided attention.
8. Look at the student when he talks to you.
9. Avoid listening and writing on the board at the same time.
10. Avoid listening and reading your notes at the same time.
11. If you must keep the student waiting briefly, recognize him and say, "I'll be with you in just a minute, Jim."
12. If you cannot avoid interrupting a student when he is questioning you, apologize and explain why.
13. Do not pretend to be listening to your students.
14. Ask questions as, "Would you give me that point again?" to be sure that you understood the question correctly.
15. Take care to restate the student's point of view to his satisfaction, such as "Do I understand this correctly...", "You feel that...", or "Your point is....?"
16. Avoid "making a speech" about the general field when a question is asked.
17. Confess your lack of knowledge if you do not know the answer. The student recognizes bluffing and loses his respect for you if you try it.

Physical Conditions

If you students indicate the need to:

-Give attention to the physical conditions

1. Check all physical arrangements carefully. Go to your classroom before the class meets and check lighting, ventilation, and heat.
2. Check and practice the use of equipment as discussed elsewhere in this book.
3. Avoid having the students facing a window, a bright light, or a moving object such as an oscillating fan when you are talking.
4. Become sensitive to outside noises when you are talking, such as fans or airconditioners going on and off, bells ringing, trains passing by, trucks starting.
5. Have a student, fellow teacher, or speech teacher make a list of outside distractions you should have been sensitive to when lecturing.

THE LECTURE AS A METHOD OF TEACHING

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SHOULD TEACHERS KNOW HOW TO TEACH

Whenever anyone comes forward with a proposal that college teachers give some attention to improving their teaching skills, invariably some resistance is encountered; although there are always those encouraging few who are vitally interested at any age or station in their careers in improving themselves.

It seems a little odd that we should even ask, "Should teachers know how to teach?" Yet it is frequently assumed that if you know your subject you are able to teach it. If this were true then that one who knows most about a subject should be the best teacher of it. Often university administrators and deans operate on this assumption in seeking new faculty, only to pull their hair after the first semester's experience with the new "great man." I remember as a student at the University of Chicago taking a course under one who enjoyed world renown and eminence in his field. In the middle of a discussion before his class he suddenly stopped; put the chalk down, and said, "I'm sorry, but I don't know how to teach this course. I just don't know how to teach it. Miss Brown, will you please take over?" His assistant conducted the class for the remainder of the quarter. How few have this insight into their own limitations as teachers; and how many fewer still would have the courage to admit it and take similar action. But how many should do just this; or better yet, how many should recognize their responsibilities in the classroom and try to improve their teaching skills. Often the individual who is a big gun as a scholar is of small calibre and an immense bore as a teacher.

The definition of a university as a community of scholars de-emphasizes the teaching function through the omission of any mention of it. Perhaps this is as it should be. Certainly a university is more than just an aggregation of teachers and taught, which unfortunately characterizes most pre-college education. Hence pre-college teachers must be certified as competent in the skills required for the transmission of a body of information, but in college teaching no such certification is required. The college being defined as a community of scholars, the grand presumption is that there is community and communication, involving both the faculty and the students, and that both these groups are made up of scholars. I am not convinced that this presumption can always be substantiated in face of the empirical evidence. Avoiding any embarrassment which might result from trying to estimate the degree of scholarship among our university faculties, suffice it to say that its incidence among our students is minimal. For the most part the college student has not learned the techniques of, nor is he very much motivated in the direction of, self-reliant and independent acquisition of knowledge. Nor is he, often enough, conversant with the skills of communication. And this is not to belittle or criticize the college student but rather to bemoan the state of affairs in pre-college education.

This state of affairs leaves us two obvious alternatives: either we accept into our university community only those who have demonstrated an aptitude and inclination for scholarship, together with the ability to communicate, or we recognize that we are supporting a misguided interpretation of the democratic ideal by trying to force higher education on as many as we can pressure into attending a university, whether or not they have the requisite capacity and motivation. I suspect we shall continue to give verbal and idealistic support to the first alternative but operational support to the second.

Being convinced that this is true, and still being oriented toward reality, I accept as part of my responsibility as a university teacher the development of a set of skills and techniques to be used in my teaching function, deliberately designed to cope with the problems of community and communication, with inadequate skills in acquisition, a marked confusion and lack of orientation, doubtful motivation and downright apathy, on the larger percentage of students. Ignoring these problems in the face of current admission practices is a stubborn or cavalier refusal to face the facts. The college instructor may excuse himself for not having majored in education, but he cannot excuse himself from the responsibility of trying to improve his teaching skills.

This is not to imply that there is any one method of teaching, or even any type of presentation which can be called the best. From the method involving one log, one pupil, and one teacher, to open circuit TV there are many techniques which are educationally successful. Here we are interested in one of these--the lecture method.

WHAT IS THE LECTURE METHOD

We speak of the lecture method. The implication is that there is more involved than just a speaker standing before a large number of students where there is little or no opportunity for teacher-student exchange of ideas through class discussion. The term suggests that there is method; that is to say, there are ways of going about it which distinguish it from a hit-or-miss, slip-shod, or unskilled presentation.

The ability to lecture well is a skill which but few possess, but which many can develop if they are convinced of its validity, and will spend the time and energy necessary to improve themselves. It involves such matters as skill in voice control, modulation, enunciation, projection, posture, gesturing; all of which come under the heading of skill in delivery. It involves techniques of gaining and holding attention; of stimulating and inspiring; of informing, convincing, and prodding to action; of commanding participation in the process by stimulating thought, by challenging creative applications; by making the class session and the course a meaningful and rewarding experience for a student.

It is not enough just to know one's subject. One must have the facility to transmit this knowledge to others. He must understand the process of communication. He must be sensitive enough to know when he is succeeding and when he is failing, and be flexible enough to change directions in the middle of a discourse.

These skills have sometimes been referred to in a depreciating way as "showmanship", or "histrionics." Let us not be afraid of words. If a professor puts on an act for purposes of self-aggrandizement he may merit any criticism he receives. However, if he has clarified his philosophy of education, and knows what goals he has in view, he may legitimately employ the means which will actualize such educational ends, and this need not rule out making a class session, or every class session, interesting and even entertaining. In such an instance entertainment is not the end, but is a means to an end.

Some teachers may attack the lecture method in an effort to rationalize their own poor teaching, laziness, or jealousy of a colleague's success or popularity. Most instructors would like to be popular with their students--and this is legitimate. Popularity in many instances indicates that rapport has been established, and without rapport the resistance on the part of the student militates against effective teaching.

DOES THE LECTURE METHOD HAVE A PLACE IN UNIVERSITY TEACHING

There is no one method of teaching. From a number of studies of teaching methods there is apparently no one method which unequivocably supercedes all others in excellence or effectiveness. There are differences in individual instructors. This suggests that one may be more effective by employing one approach, while another would be more successful with a different technique. The criticisms leveled against the lecture method might have been more justly directed toward the attempt by one ill-equipped to do so to utilize the lecture method before a class of 200 when he is actually at his best in a small discussion group of 12 or 15 students, or in a seminar of four or five. Also, some material lends itself very well to the lecture method and vice versa. Our thesis here is that there are ways to make the lecture method academically effective. It is the purpose of this discussion to indicate how this may be accomplished.

Such a discussion is indeed timely, in the face of burgeoning enrollments and lagging teaching resources. We must either find ways to teach larger and larger classes, or prohibit the enrollment of over a million students in the next year or two, according to the estimates.

Surely, as educators, scholars, scientists, and research specialists we need not be intimidated by the problematic aspects of this situation. As the "problem solvers" of our contemporary society we can certainly relish the challenge of solving problems connected with our own function as teachers. One of the first steps in scientific investigation is the identification and isolation of personal prejudices and individual biases. Regardless of what our thinking about the lecture method has been in the past, let us at this time with open minds consider its possibilities. Here we need to utilize to the fullest our creative imaginations which will emancipate us from the restrictions of outmoded academic tradition; or at least allow us to re-examine the adequacy of the methods of the past for meeting the academic problems of today.

The problem can be clearly stated: the shortage of teachers is becoming more critical each year; while student enrollment threatens to double very shortly. What do we do? Deny college education to fifty per cent of those asking for it? This violates our cultural and social philosophy. Double the pool of college teachers? This idea is fantastic in view of current college salaries and the pirating by off-campus agencies. It appears that our solution will lie in discovering methods of teaching more students with the resources we have. The lecture is one such method.

> "A good teacher is so full of his subject and so impelled by the desire to unfold its beauties and marvels to others that he seeks constantly for approaches which will get through to the inert, the inept, the inattentive, and the unawakened. Method for him grows from a continuing search for means of arousing alike in the jaded and the unsated a hunger for knowledge and meaning and of feeding whetted appetities with the best that his field can offer. The motive power for such a teacher consists of the twin urges to know and to share; and the fuel that keeps him going is compounded of a body of specialized knowledge constantly expanding within an enveloping field of general knowledge under the spark of continuing inquiry."
>
> ——Francis S. Chase
> Dean of the Graduate
> School of Education
> University of Chicago

WHEN IS THE LECTURE METHOD INDICATED

There are varied opinions as to optimum class sizes. These opinions for the most part are reflections of individual preferences and personal experiences, together with skill and success in dealing with classes of varying sizes. My own biases are these: When a class numbers more than thirty there may as well be three hundred. The discussion method begins to deteriorate when there are more than thirty students.

The carrying power of the voice of the teacher is a variable. Some persons can project to the back wall of a room holding 1500 persons, while another has difficulty making himself understood with thirty. The quiet voice can sometimes be amplified by the use of a microphone. But even with this advantage the platform skills of the instructor must be taken into consideration. So, we must say that the instructor is a most important determinant. When a department chairman discovers that he has a very good platform person on his faculty he may set about to utilize his skills in those courses that are swelling in numbers and are being closed out at registration.

The lecture method may be resorted to when there is on the faculty very limited teaching resources for an essential subject. In order to accommodate the needs of the students in terms of curriculum demands a single resource person may be asked to take into his classes many times over the number normally assigned. It is not enough to say that the administration should employ more faculty. The realistic fact is that in just such essential courses faculty is getting harder and harder to find.

The lecture may be indicated for introductory or orientation courses, where the content is mostly informational, factual, and relatively non-controversial. It may be indicated where the purposes are largely inspirational, motivational, and slanted toward the development of certain attitudes and values. It may be utilized for survey of a field where issues and controversies may be identified and discussed in terms of latest developments--which issues will be considered more in detail in later specialized courses.

In summary, the lecture method can be regarded as a function of class size, of available teachers skilled in platform presentation, of ratio between essential material and faculty specialization, and of course content.

HOW LONG SHOULD THE LECTURE BE

The length of the lecture will be determined by a number of things. The customary lecture period in college is fifty minutes. This may be varied under some circumstances. For example, in our Department of Psychology at the University of Miami we teach one large section of Introductory Psychology by closed circuit TV. The lecturer holds forth for thirty minutes, after which discussion leaders in the various receiving rooms take over for the remaining twenty minutes. On the other hand we lecture to other classes which remain in session for one hundred minutes without a break, apparently without resentment or lagging interest on the part of the students.

Perhaps the most determining variables are course content and skill of lecturer. The motivation of the students cannot be ignored. Graduate students will as a rule sustain interest longer than freshmen.

HOW OFTEN SHOULD LECTURES BE SCHEDULED

One cannot talk about lecturing and the frequency of lectures without serious consideration of the type of material to be dealt with. We have already said something about when the lecture method is indicated. Conceivably in some instances the lecture method is entirely contraindicated. In some situations the entire course of forty-five sessions of fifty minutes each might be handled totally by lectures.

Perhaps in most courses there is a portion of the content which lends itself to presentation through lecture; whereas other parts might better be taught in discussion, demonstration, laboratory, or seminar sessions. A careful analysis, coupled with experience, should provide guide lines in determining how often lectures should be scheduled in a given course.

However, even in the lecture method it must not be assumed that the teacher is restricted only to oral presentation. Other senses than the auditory may be stimulated through a judicious use of visual material--movies, charts, slide and opaque projections. Motor participation may be involved through the assignment of projects outside the class. Give-and-take discussions may be generated if these projects are group assignments rather than individual.

CLARIFY YOUR OWN PERSONAL PHILOSOPHY OF EDUCATION

If you intend to employ the lecture method in teaching your classes, your preparation should extend much further back than just the mechanics of speech making. As a matter of fact, if you are going to teach at all you should clarify your personal philosophy of education. This is essentially a matter of determining what you are trying to teach, and why you are trying to teach it. As Hutchins has indicated, the answers to these questions "will be predicated on our conception of man and of society."

I am aware that the contribution which I was asked to make to this institute concerns the process of lecturing successfully. But underlying and supporting the process is its ultimate place in a context of meaning--and this is its philosophical complexion. Inevitably, this leads to a consideration of values; that is, to what we hold to be worth while.

In this connection what do you consider the proper aims of education? Is education "good" itself? Is it simply the transmission of knowledge, or does it include some effort to develop wisdom in the use of that knowledge? What is the role of a university in education? Is this the place for indoctrination and propagandizing; or more properly for developing a critical facility, and independent, creative thought? Has it fulfilled its function when it has trained young persons to take their places in the vocational world? What is the result of education in terms of factual know-without attention to orienting values centering around a philosophy of man?

Your effectiveness as a speaker will be related to your personal attitudes and values connected with the educational process and your place in it. A good actor may be convincing in a part which is totally alien to his own personality, but a teacher, meeting the same class three times a week for sixteen weeks, cannot successfully camouflage gross discrepancies between what he says and what he really thinks. "I cannot hear what you say for listening to what you are."

The "how to" is always predicated on the "with what." What you are philosophically--your convictions regarding the goals of education; your attitudes toward students; your enthusiasm for your field and your degree of dedication to your profession; your concept of yourself--all of these constitute the substance underlying methods of presentation.

Are you teaching engineering to help the student make a better living or to make a better life? Will you present the concepts of engineering and let it go at that, or will you relate these concepts to other diciplines and other values possibly held by the student in order to give added meaning to his interest in engineering? I. I. Rabi, professor of physics at Columbia, said this:

> "Wisdom is by its nature an interdisciplinary thing and not the product of a collection of specialists. . . . The Scientists must learn to teach science in the spirit of wisdom, and in the light of the history of human thought and human effort, rather than as the geography of a universe uninhabited by mankind. . . . The non-scientific faculties must understand that if their teachings ignore the great scientific tradition and its accomplishments, however eloquent and elegant their words, they will lost meaning for this generation and be barren of fruit."

Will you relate engineering and its challenges to man's continual search for a more rewarding life through the conquest of material forces, and will you be able to articulate this with the more fugitive, non-material values without which the whole engineering enterprise would be meaningless? Is engineering not to be spoken of in the same breath with aesthetics and beauty, or is it so often seen only as cold and practical simply because in our approach of it we have been insensitive to, and hence have made no mention of, its beauty? Will we teach engineering as a total way of life, or see its practice only as a pursuit of the many interests and activities of a healthy functioning whole person? Are you interested, in other words, in turning out engines or engineers? The first is a machine; the other is a human being; or could be.

If you are trying to teach no more than the material of engineering, and you believe your responsibility to the student ends there, read this quote from Naomi White, Stillwater High School, Stillwater, Oklahoma:

> "I have taught in high school for ten years. During that time I have given assignments, among others, to a murderer, an evangelist, a pugilist, a thief, and an imbecile.
>
> "The murderer was a quiet little boy who sat on the front seat and regarded me with pale blue eyes; the evangelist easily the most popular boy in the school, had the lead in the junior play; the pugilist lounged by the window and let loose at intervals a raucous laugh that startled even the geraniums; the thief was a gay-hearted Lothario with a song on his lips; and the imbecile, a soft-eyed little animal seeking the shadows.
>
> "The murderer awaits death in the state penitentiary; the evangelist has lain a year now in the village churchyard; the pugilist lost an eye in a brawl in Hong Kong; the thief, by standing on tip-toe, can see the windows of my room from the county jail; and the once gentle-eyed little moron beats his head against a padded wall in the state asylum.
>
> "All these pupils once sat in my room, sat and looked at me gravely across worn brown desks. I must have been a great help to those students--I taught them the rhyming scheme of the Elizabethan sonnet, and how to diagram a complex sentence."

HAVE SOME KNOWLEDGE OF HUMAN NEEDS AND MOTIVATION

First of all a successful teacher will have some general knowledge of the nature of human needs and motives. As I am a clinical psychologist you might have suspected that any suggestions I had to offer would be predicated on certain psychological assumptions. Underlying and motivating the greater part of human behavior are four major psychological needs. The student is constantly driven to find satisfaction of these needs in all aspects of his life, including his experience as a college student. The instructor is constantly driven to find fulfillment of these needs in all phases of his life, including his experience as a teacher. A thorough understanding of this may furnish us a key to much of the success and of the failure in college teaching.

These four major psychological needs, as I see them, are as follows:

1. The need for a sense of physical and economic security;
2. The need for a sense of personal worth;
3. The need for a sense of being loved and wanted--of being desirable and acceptable as a person;
4. The need to make meaning out of experience.

As we explore some of the details of lecture presentation, we shall note the influence of these needs as they affect the student and the instructor. At this point we note that the needs are legitimate. There are, however, both healthy and unhealthy means of satisfying them.

For example, in reference to the need for a sense of physical and economic security it is legitimate for an instructor to expect to be paid for his services, and to put his weight behind efforts designed to bring about an income more equitable in terms of training and experience. But one who knows when he enters teaching, or discovers soon after, that the pay is much below equity, but remains in the profession in a chronic state of frustration and tension, self-pity and griping, is not apt to make a successful teacher. His resentments and hostilities will probably be expressed in a sloppy job, indifference, apathy, aggression toward his students and bickering with his colleagues. Trite as it may sound, teaching is a dedicated profession--it has to be in order to overcome the emotional effects of abbreviated income.

Even the dedicated instructor must recognize that the student is in great part the product of a society which honors material success above all else, and hence not become too impatient with him when he persistently inquires as to the value of a given point of view in economic terms.

The successful instructor will also recognize the need of the student for a sense of personal worth, or as we sometimes put it, "ego needs." Anything in the attitudes or actions of the instructor which threatens or does violence to such a need is going to be met with resistance and resentment, and an unconscious attempt of retaliation through refusal to study or meet the assignments, or other measures. Communication is minimized. Rapport is absent.

On the other hand, when the instructor has a genuine respect for the student--his young colleague in the scholarly enterprise--he will avoid many pitfalls and errors which promote failure in teaching. He will compliment wherever and whenever he can. He will temper necessary criticism with patience and understanding. He will never ridicule. He will respect even the less well-endowed student as an individual, knowing that his lack of intellectual capacity is no fault of his own and that, although perhaps misplaced in a university, he is usually there because of social pressure and social misinterpretation of the function of a university rather than as a wilful intruder. The wise instructor will recognize that it is often out of this need for a sense of personal worth that the student makes audacious statements, draws premature conclusions with an absoluteness that is sometimes admirable, and is more intent on winning an argument than on discovering a fact.

But the instructor too has a need for a sense of personal worth. In a healthy way he may derive fulfillment of this need from his teaching. If he regards himself as a second-class citizen, however, if he is filled with unresolved conflicts over his status or his own worth as a person, it is probable that these tensions will be expressed in neurotic compulsions to reassure himself and to impress others with his importance. This may take the form of browbeating students, aggressive assertion of his prerogatives as instructor, refusal to entertain any criticism that threatens his intellectual and academic authority, inability to recognize an exceptional student as intellectually superior to himself. He will meet honest contradiction with ridicule, a brush-off or a merciless attack on the student--the result being again that any hope of communication is destroyed. The need to give an impression of importance, profundity and authority will often lead the teacher to phrase his remarks in language incomprehensible to the student because of the level of vocabulary or the use of esoteric gobbledygook. Again no communication.

Even though an expert in his field, the teacher should wear the cloak of humility if he hopes to establish rapport and to communicate with his students. Any superiority that he may actually have should be manifested in the content of his discourse, not in his personal attitudes. Aloofness, arrogance and other forms of the "superior" attitude usually stem from an underlying weakness in the person's own ego structure--he is fundamentally unsure of himself.

Another major psychological need which should be recognized and understood is that of being loved and wanted--a sense of "belongingness," of acceptability as a person. It is expressed in the attitude of the teacher toward the student as warmth and accessibility, as empathy, as an effort to "get with" the student and understand him. This need on the part of the student will frequently impel him to make an extraordinary bid for attention and consideration from the instructor. This should be understood and handled with sympathy. The college student is often away from his usual sources of immediate affection--his own family. He may seek satisfaction and reassurance from an instructor, who has become something of a parental figure in his perceptions.

The same need on the part of the instructor may lead him to seek extra-academic alliances with his students or to reduce his objectivity to such a point that the situation becomes academically suspect. It may make him "soft" in his grading practices and in the demands he makes on his students for adequate preparation. Out of his own needs to be considered "a good Joe" he fears to offend or to generate any resentment against himself as a person. If his own needs for affection have reached such neurotic proportions, his adequacy as a teacher may be jeopardized.

The need to make meaning out of experience affects both student and teacher. It is mostly because of inability to fit much of the educational process into any system of meaning that there is a general apathy on the part of students. This may stem from a tendency of educators to view education as an end in itself rather than as a means to larger ends in the human enterprise--sometimes even to consider individual courses as ends in themselves. When this attitude obtains, the aim of the student is to avoid certain courses if possible, and if not, then to pass them as expeditiously and as painless as possible, even if he must have recourse to dishonest tactics in order to accomplish this goal. The course, and education in general, are viewed as one of the unavoidable distresses inherent in our current society's initiations rites--unnecessary pain and torture to test the endurance and establish the acceptability of candidates for higher social membership. The emphasis is on the symbolic social significance of passing grades and degrees rather than upon producing educated persons.

In his own unique and individualistic way the instructor should strive at all times to make the classroom experience meaningful to the student. This of course can be accomplished much better if it is meaningful to the instructor himself. Orienting attitudes might center around such questions as: How does this material relate to a system of values in general? How does it relate to other fields of inquiry? How does it relate to what has already been learned and what one may wish to learn? What significance does it have for the living experience? What enrichment does it promise for the individual and for society? How is it related to the student's (and the teacher's) self-actualization? I do not know of any single thing which will make the teaching experience more gratifying for the instructor and the learning experience more gratifying for the student. Nor do I know of anything--not even the increase of monetary rewards--which will increase the motivation to teach and to learn; nothing which will revitalize classroom relationships and experiences as will finding for them a significant place in a context of meaning. When this happens the teacher has no urge to sell his profession or his own field short. He speaks with conviction. The importance of his subject is established. He becomes an inspiration to his students.

KNOW YOUR SUBJECT

Earlier we remarked that it was not enough simply to be an expert in one's field in order to be a successful teacher. We did not intend to underemphasize the importance of being informed. One must have information before one can impart it.

Francis S. Chase, Dean of the Graduate School of Education at the University of Chicago has this to say:

> "I hold that young people are more likely to become students when their teachers are scholars.
>
> "One who teaches without having the passion to know is not truly a teacher, but a propagandist, or perhaps an evangelist or a reformer. He is driven by a passion to convert or to mold human beings. That may be a noble passion, though it often assumes the ugly form of fanaticism; the passion of the teacher, is to expose minds to new truth."

DETERMINE THE PURPOSE OF THIS LECTURE

The teacher should determine in his own thinking what he intends to accomplish in a specific lecture period. In general terms this would be to entertain, to inform, to convince or persuade, to instill some value, or to inspire, motivate, and stir up enthusiasm. Certainly among possible purposes should be the encouragement of the student's own thinking and the development of his critical capacities.

Specifically, the instructor should have in mind the content he wishes to communicate (facts, figures, statistics, a formula, etc.); principles; applications; research methodology; and such. He should have a goal in mind for each lecture hour--a purpose which he can clearly enunciate.

ORGANIZE YOUR LECTURE

The purpose clearly defined becomes an integrating core around which the lecture can be prepared in a well organized manner. Preparation for the particular class period becomes an essential which is often minimized. It should entail careful organization of the material. When you organize you clarify your own thinking. In addition, a well-organized presentation is much more easily followed by the students. Note taking is less confused and may even be minimized. Such organization enables the student to grasp, to understand and to remember more adequately what you have said. In a class where the material is extensive and complex, and where so much is original that the student cannot depend on the textbook to discover the instructor's organization, it is helpful to pass out mimeographed outlines of what will be discussed in the immediately forthcoming sessions.

Organization however does not imply the complete writing out of a dissertation, and certainly not the memorizing of it. Spontaneity in a teacher is one of his greatest assets. But spontaneity without direction would be classroom chaos. Direction can be provided in a very practical way by the use of 3" x 5" cards on which the instructor has jotted down the salient points of his discussion. These can be held in the hand and referred to without undue attention. Their use allows for freedom of movement on the part of the speaker. They are not distracting and are easily manipulated. This does not mean that a manuscript is taboo. Whereas in a public address the use of a manuscript is often detrimental, its use in scholarly discourse may be not only permissible but advisable, to insure accuracy of information, completeness and even the inclusion of a well-turned phrase that seems to be semantically effective--in short, to insure better or more artistic communication. We cannot dismiss style as irrelevant in the presentation of material at university level.

> "For good or ill, your conversation is your advertisement. Every time you open your mouth, you let men look into your mind."
>
> ——Bruce Barton
>
> "Industrial Arts & Vocational Education"

The instructor never knows just what directions in thought, interest and expression his class will take. Even the most experienced of teachers cannot always calculate these variations ahead of time. A cut-and-dried adherence to a manuscript or outline will not allow for such eventualities. The teacher who is actually student-oriented, and who is more concerned with the development of the student than with the development of a theme, should be able to modify his approach at a moment's notice. He must learn to think on his feet. He must be free to give his attention to the situation, to evaluate constantly the effectiveness of communication, student response and the clarity with which he is developing his thought. He cannot do this if his attention is devoted to trying to remember word for word what he had prepared to say. Spontaneity in an instructor may spell the difference between success and failure. His classroom presentation should indicate that he is alive and that his brain is actively creating rather than phonographically reproducing.

PREPARE SUPPLEMENTARY MATERIAL FOR THE STUDENTS

Some lectures are of such a nature that their effectiveness is minimized if the students are more attentive to taking notes than to listening to what is being said and thinking along with the speaker about the subject. To preclude this it is often wise to prepare mimeographed material to be handed out as the class begins; at some point in the lecture; or after the lecture, as may be most suitable.

In very large sections graphic material in the students' hands may be better followed than a diagram on the blackboard, which because of distance, poor lighting, or reflections may be difficult to see.

References to outside reading, future assignments, and general announcements may be handled in this fashion when the effectiveness of the lecture would be interfered with by oral presentation.

The students will be intent on looking over anything handed to them at the beginning of the class; so, unless the material is essential to better comprehension of the lecture at the time, it is better to hand it out as the class leaves. Thus it will not distract as it might otherwise.

It is sometimes a judicious thing to prepare a syllabus outlining the lectures, and incorporating the important concepts and references, which the students may purchase. This usually eliminates the need to make assignments and many other references which might clutter up a lecture period.

THE OPENING

Having some general knowledge of the nature of human needs and motives, informed in his field, prepared for this particular presentation, clear as to his purposes, the instructor meets his class.

Get off to a good start. Command attention of your audience from the outset. Do something to make certain that you have their attention and that no one is asleep or dozing. Wake them up. Be alive.

We experience things very much as we expect to experience them. In psychology we call this "mental set." If you start off in a listless apathetic way, the audience is apt to expect the rest of the lecture to be just as dull. Then, even though you later bring in interesting episodes, you may fail to get an alert response from the audience because they have settled down to endure what they expect to be a boring experience. On the other hand, if you succeed in getting your audience on the edges of their seats at the beginning, alert and attentive, they will anticipate a vitally interesting lecture, and this very anticipation will tend to make them unaware of the less colorful passages of your presentation. So put some punch into your opening.

How may this be done? The device which is used most often by speakers is to tell a sure-fire joke; or two or three jokes. It is better if these can be related to the subject matter of your lecture. The joke has the advantage not only of gaining attention (because everyone likes a funny story), but also of pulling the audience together by getting them to laugh together. It is even more effective if the joke is on you. Certainly you must be very careful not to make your students the brunt of the joke. Also, you should avoid dialect jokes where the use of dialect may be offensive. Be prepared for the joke which doesn't go over. Pick up fast with something else.

Next to the joke the most often used attention-getting device is the anecdote. A little story about people and things, especially if the students are familiar with them, arouses attention immediately. Edmund Fuller said, "Anecdotes are stories with points. They are tools--nail-sinkers to drive home arguments firmly. They are the origin of all teachings." The anecdote does not have to be humorous, although it may be. It can be quite serious. Its chief feature in addition to its attention-getting value is that is usually leads up to the making of some point pertinent to the discussion to follow. It may very well set the stage for stating the topic of the lecture. For example, suppose the topic of the lecture is "Pre-stressed Concrete." You might open your lecture something like this:

"I wonder how many of you read or remember Judge Ben Lindsey's book "Companionate Marriage." Of course if you admit you remember it, this will immediately date you as it does me. I happened to come across it a few days ago, and took enough time to glance through some of its pages again. The judge was advocating something very radical about marriages. He was suggesting that a young couple live together about one year before they really got married, in order to see if they could endure each other for the rest of their lives. The judge pointed out that during a year the young people would experience the stresses and strains which usually characterize marriage. The first year is the hardest, they say. If the couple went through this experience successfully they were ready then to set themselves to it on a permanent basis, as any later stresses were not likely to exceed these. I suppose we could call this "Pre-stressed marriage." It reminded me of what we are going to talk about today--pre-stressed concrete. The two have very much in common."

After gaining attention with this little story the lecturer is now in a position to elaborate on the principle of pre-stressing a concrete beam before it is placed permanently, in order to insure that it will carry any future load which is likely to be placed upon it. So, we may start off with a joke or an anecdote or with both.

Another way of commanding immediate attention is to come out in the beginning with a jarring or shocking statement, like:

"I want to share with you something that very few people realize--that one-half of all the people in the United States are below average intelligence. Did you know that? Incredible isn't it?"

After pausing to let this sink in, and after a few gasps on the part of the students, the teacher may then move into a discussion of the significance of the statistical mean or average, which of course divides any set of data with fifty per cent above and fifty below.

The newspaper is a good source for the joke, the anecdote, or the shocking statement. Usually there are a number of items which can be related in some way to the topic of the day. Attention may be greater if this is done inasmuch as the student may have read the same item and will wish to see what application you make of it; and because it is timely, referring usually to something in the world of affairs that is taking place right now. Even the campus paper will provide many excellent leads. Commonly known current events whether in the paper or not may be used in a similar way--the football game, school election, etc.

Action is always attention-getting. If you have a guest speaker, do not have him seated on the platform, but in the audience. Make your introductory remarks including a little anecdote about him, and then have him come up to the platform from his seat in the audience. This makes for suspense and interest.

If you intend to use demonstration material--charts, models, and such--have these brought onto the platform after the audience has assembled. This will whet their curiosity and make them more eager to see what is going to happen.

If you are going to lecture on the principle of leverage or cantilevers you might go at it by starting off like this:

"Do any of you students need any money? (Imagine!) Well, here's your chance. I'll bet any one of you one hundred dollars that there is not a person in this room who can lift me off the floor, even Jim Blaney sitting back there, our right tackle."

After the excitement dies down a bit, you continue, "Well, alright. Let's leave the money out of it. Professors are not supposed to gamble with students anyhow. Come up Jim and try it."

You then say, "Now the first time he will lift me just to prove that he can. Then watch carefully to see that I don't change my position, and he will not be able to lift me the second time."

You have him catch you under the arm-pits as you put your hands on his shoulders to steady yourself. He lifts you without any trouble. Then you say, "Now notice to see if I change anything. This time, Jim, you cannot lift me."

As he crouches for the lift, press back ever so lightly on his shoulders in order to hold him a fraction away from you. Do this so he will not be aware that you are holding him away. He will then, to his amazement, and to the wonder of the entire class, be unable to budge you from the floor.

You now really have their attention. They want to know how and why. You now have a most receptive audience to hear you explain that as a given weight is extended further out on an arm from the point of the fulcrum that the force needed to balance this at a stationary point on the other side of the fulcrum will increase geometrically.

A dramatic episode can certainly get the lecture off to a good start if it is carried off successfully. For example, when I am scheduled to lecture on psychosomatic principles, I sometimes begin by spotting a student in the front row; glaring at him a few seconds, and then almost shouting, "What do you mean, young man, showing up in this class after what happened? How can you have the nerve to come back here?"

The class is on the edges of their seats.

"Stand up here just a minute. No wonder your face is red. Class, please notice how really crimson his face is. Now, Joe, before this class I wish to apologize to you for using you in this manner. I'll try to make it up to you. Please sit down. If you will notice, not once did I touch this student. I did not rub his face to make it red. With nothing to stimulate him but ideas we have brought about an abnormal dilation of the blood vessels in his face, so much so that it took on a crimson hue. Had I mentioned that there was a live snake slithering under this young lady's seat we might have seen just the opposite--a constriction of the blood vessels in her face making it appear abnormally white."

The teacher has demonstrated the basic principle in psychosomatic disorders--that the actual physical processes of the body respond to ideas, especially if they are emotionally charged. The students will never forget it.

We have presented several ways to gain attention at the opening of a lecture. Of course, since the teacher may lecture to a class as many as forty-five times during a semester it will take some ingenuity to vary the approach enough to keep the students guessing what will happen next, but between the joke, the anecdote, the jarring statement, the use of news items and current events, action, and the dramatic episode, singly and in combination, it can be done quite well.

ESTABLISHING RAPPORT

Get with your audience. Get your audience with you. Establish rapport.

Be friendly. The open invitation to friendly relations is the smile. Professors, sometimes regarding themselves as pundits, frequently feel that they must present a deep meditative countenance to play the role properly. Or they may intentionally or unintentionally hold themselves aloof from the student, or assume the superior attitude. Students may be impressed with this in a visiting lecturer, but to face it three times a week for sixteen weeks is too much.

In most colleges the class constitutes a captive audience. They must attend and they must remain. (There are a few encouraging exceptions.) As a consequence the instructor may not be motivated to extend himself in trying to get with his class. Of course, some instructors do not regard teaching as their primary interest. Research, prestige, or salary may supercede doing a good job of teaching.

I am aware that there are varying opinions as to how friendly or how impersonal the instructor should be with his students. My own conviction is that the instructor can be a more effective teacher, that he can motivate his students more highly to learn, and that learning is improved--at least in the large lecture-type class--if an atmosphere of warmth and friendliness prevails. And this may take place without any loss of dignity on the part of the instructor, and without taking recourse to a buddy-buddy type of relationship. Undue familiarity, of course, may weaken the academic influence of the teacher. Basic to all this is a genuine feeling of friendliness toward people, and toward students in particular.

Identify with the students. Remember your own college student days. Appreciate the problems and the point of view of your students. Let them know you see the situation as they see it; that you understand their outlook and attitudes. Groan with them over the loss of the football game. Rejoice with them in victory. Remark on your own student days--the problems and the pitfalls and how you saw it then--how you thought you'd never make the long haul, but how you did.

Of course, this whole matter of rapport and identification with the student is not restricted to the classroom. The student will be aware of how much interest you take in student affairs in general; whether or not you attend their special events; whether you respond to invitations to their social and organizational affairs.

Be generous with the sincere compliment. When an individual in the class has won some distinction, speak of that before the entire class, remarking how proud you are, and call upon the student to stand and be recognized. If the entire class can be complimented for some performance, utilize this to increase rapport between you.

Never ridicule or belittle a student. Students identify with each other. They see the teacher using an unfair advantage when he bawls a student out before the class, or otherwise embarrasses him. The larger part of the class will resent it.

A sense of humor is indispensible in the large class situation. With so many people so many things can, and do, happen. The speaker must be able to laugh--and especially be able to laugh at himself. He must be able to take it if the joke is on him.

Anything we have said or can say about establishing rapport is ultimately predicated on a personal philosophy which regards the student as a person of worth and dignity in his own right, and as a colleague in the scholarly enterprise. This rules out either direct or indirect exploitation of the student for personal ends, or considering him just a necessary evil to be tolerated out of expediency. It involves providing an emotional climate most conducive to the student's growth, expansion, and self-actualization.

Part of what we have said applies to the initial phases of the lecture. Other matters apply to the continuing effort throughout the lecture to maintain rapport with the students.

Get across to the student that you are there to help him--not to ride herd on him.

STATE THE PURPOSE OF THIS LECTURE

In the introductory phase the purpose of this specific lecture usually should be stated. This provides the student with a core around which he can integrate the more extended remarks which follow. This can make everything fall into place which without such a statement may leave the student vague and confused.

Of course, the teacher should have clarified his purpose before coming before the class. Specifically he should convey to the students what he shall attempt to accomplish this hour. This is disciplinary to the thinking of both instructor and student. It helps create alertness on the part of the class. It furnishes a yardstick for evaluation. It was either accomplished, only partially accomplished, or accomplished not at all. It helps avoid the feeling students so often have of being left dangling at the end of the class. They heard a lot of words, but what did they all mean? You might say something like this:

"We now have left in this period forty-five minutes. I believe in this time we can clarify two points. If we don't succeed you let me know and we'll try again. Now, first of al ....
Then secondly....................."

The student will wish to see how well you succeed, hence will be more attentive than if the lecture simply begins without such an orienting statement of purpose.

ESTABLISH THE IMPORTANCE OF THIS LECTURE

The importance of accomplishing the purpose of this lecture should be established. Is it significant? If not perhaps the time should not be wasted. If it is, you should be able to state what that significance is. If the teacher is just marking time; if he lectures in a perfunctory manner, or assumes a supercilious attitude, he need not be surprised if his class shows little interest in what he is saying, doesn't take him seriously, or goes to sleep.

The need to make meaning out of experience is one of the great psychological needs of each of us. If the teacher cannot enunciate the worthwhileness of his subject he should reconsider the wisdom of its inclusion in a course. If he is convinced of its importance then it merits the effort to make it alive and significant for the students in such a way that the student may be stimulated to join in the academic adventure of exploration, discovery, and mastery.

> "Knowledge cannot be transferred from one person to another; it has to be reborn in the recipient's mind. To accomplish this, certain mental activities must be aroused. More telling will not do it. Teaching is not completed until what the teacher wishes to impart becomes a part of the learner's mentality. The decisive element in the teacher's art is stimulating the appropriate activity in the pupil's mind,

and this cannot be done without the proper excitement of mental energy awakened in the proper way."

——————George B. Cutten
President Emeritus, Colgate University
in School and Society,
Jan. 31, 1959.

THE MAIN BODY OF THE LECTURE

Now you have prepared your class and are ready for the main body of your presentation.

Having gained attention in the beginning, you then have the problem of holding it. Our of laboratory experiments psychologists have found the following to be most effective means in holding attention: (1) Movement commands attention better than the static. Get action into your presentation. With very large classes, for example the breast microphone is superior to the stand "mike" which holds the teacher glued to one spot. (2) Novelty gains more attention than the familiar. Endeavor to inject something new into your presentations once in a while. (3) Variety is superior to dull repetition and routine. (4) Intensity, involving sound, color, size, tone of conviction or emotion is naturally more attention-demanding than a bland, innocuous, limp presentation. (5) Contrast gains over uniformity. This applies to inflections of the voice, to seriousness and lightness, to intensity (continuing intensity without contrast can of course become monotonous and ineffective.) (6) Visual material rates higher than the strictly verbal. The judicious use of visual aids, charts, slides or movies, especially if colored, of models or demonstrations, will make otherwise dull material come to life. But the use of visual aids can be overdone. One instructor used so many films that the university authorities finally decided all they needed to conduct the course was a projectionist not a professor. (7) Where visual aids are not available, or for any reason are not used, the instructor might make very effective use of visual images. Most persons think in images. This suggests that a total reliance on abstraction should be avoided. Illustrate frequently with references to familiar, concrete situations. The image will be remembered long after the words are forgotten. (8) Emphasis is closely related to intensity, but differs enough to deserve separate mention. A class discussion might be punctuated by such expressions as "Now, this I want you to notice especially," or "If you get this one point to take home with you our tine will have been well spent." (9) Class participation invariably makes for more alertness. With the trend toward larger classes this is not always feasible, although traveling microphones may facilitate student participation in a large class. (10) Enthusiasm, sincerity and conviction on the part of the teacher will be emotionally contagious, engendering a more positive and attentive response from the class. (11) The tried and proved rhetorical device of tying in whatever you have to say with the values already held by the class, such as health, happiness, success, personal enhancement, intelligence and so on, helps in giving meaning to the classroom experience.

In short, teaching requires more than a cut-and-dried statement of information, however accurate or important this may be. To teach successfully the instructor _must_ gain and hold the attention of his students. He must keep them awake and he must keep them interested. He must find ways to open their minds so that they will be receptive and critically evaluative of what he has to say.

One further device for holding the attention of a class is that of _talking with the students_. Look directly at this one and that one. After going to the effort to establish rapport the instructor should not leave the class by gazing off into space. By the device of direct attentiveness to the student the teacher can be more sensitive to his reactions and thus be ready to modify his tactics when he senses for any reason that communication or interest is falling down.

ASK QUESTIONS

Since your audience is too large to permit much two-way discussion, a good device for this type of teaching is to inject a question yourself now and then which students would be likely to ask if they had the opportunity. It might go something like this:

"Now, I wonder if I have really made that point clear. I notice some of you seem puzzled. Perhaps you'd like to know if there is any experimental evidence for the conclusions I have just drawn. Yes, there is; and here it is."

Or:

"I can hear some of you asking now, 'Professor, what possible significance can this stuff have for me,' or 'By what stretch of the imagination can what you have just said have anything to do with this course?'"

When you ask a question such as these you bring your students more definitely into the situation; whereas pontifical pronouncements may fall on deaf ears.

Questions from the class need not always be taboo. When such a question is entertained, the instructor should be certain everyone has understood it, or he should repeat it so all can participate in the exchange of ideas.

THE ENDING

Try to arrange for a strong ending. This is as important as the beginning. Avoid letting a class session dribble off. Many lectures are weakened in effectiveness just because of a weak ending. There are a number of ways a lecture may be brought to a more impressive ending, for example:

Ask a question, and leave it with the class to cogitate on, promising an attempt to answer it at the next meeting; or

End on a quote, especially if the author is well known to your audience; or

End each period with "What to do," or "How to use this"; or

Summarize. Your summary is a recapitulation--a miniature review--of what you have said. But make it brief. Don't give your entire talk over again.

One good device is to state, "Now, I know that it would be difficult to remember everything we've discussed. Let me try to pin-point it." Then summarize briefly and, if it is appropriate, suggest a course of action. And, taking my own prescription, let me summarize our remarks:

PRIOR TO COMING BEFORE YOUR CLASS

1. Have some general knowledge of the nature of human needs and motives.
2. Be informed in your field, or about your subject.
3. Be prepared for this specific class session.
4. Determine your purposes and intentions for this hour.

BEFORE THE CLASS

1. Command attention immediately by word or by action.
2. Find a basis for a sincere compliment if you can.
3. Indicate what you expect to accomplish.
4. Establish the importance of this hour's discussion.
5. Make your presentation.

6. Hold attention through movement, novelty, variety, intensity, contrast, visual materials, visual imagery, emphasis, class participation, enthusiasm, sincerity and conviction, and by tying your presentation to their values.
7. Maintain flexibility and spontaneity.
8. Talk with your students. Ask questions.
9. Try for a strong ending.
10. Suggest a course of action.

A COURSE OF ACTION FOR YOU

1. Have a regular plan of study in your field, including review and expansion.
2. Keep a scrapbook or file for articles, notes, jokes, and anecdotal material pertinent to your field, and possibly useful in lecture.
3. Collect commonly asked questions, and be prepared with answers.
4. Listen to other effective teachers. Analyze their methods. See how they accomplish the things we have discussed here.
5. Work for improvement in the mechanics of your speech.
6. Try to work in at least one new improvement with each class you meet.

Now in conclusion, it must be understood that there are no mechanical devices which will insure successful teaching. It appears as a flowering whose source of nourishment lies in unseen roots--the attitudes, the outlook, the personal philosophy and the frame of reference of the teacher. Education is a process of personal growth and development. And you cannot force any living thing to grow. The best you can do is provide a climate and atmosphere most conducive to the full actualization of the potentials resident within that living thing, whether it is a mustard seed or a student of engineering. Teaching is not a process of doing something to the student. It is a matter of creating a situation and a relationship which will activate, encourage, and nourish those capacities for growth already within the student. If the teacher will bear this in mind and avoid exploitation of the student and class to satisfy his own egocentric needs, mechanics become but secondary adjuncts to successful teaching. Hence, the last thing I would wish to do would be to present you with a rigid set of rules and procedures, or a detailed account of my way of teaching, with the implication that you would do well to emulate it. One's own personal style evolves, not from aping another teacher, or playing a role as it has been defined by someone else, but out of one's own unique resources.

RECITATION AND DISCUSSION

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The sturdiest competitors with the lecture method of teaching have been the varied techniques grouped under the heading of discussion-recitation. However comparisons of the over-all effectiveness of lecture vs. discussion have usually been deficient in analysis of the strengths and weaknesses of each. For example, the rate of transmission of information is usually lower in discussion than in lecture or printed materials. Consequently we would not expect discussion to be especially effective when the primary goal of teaching is to transmit information.

However even when transmitting information is the major goal, discussion techniques may be useful at some stages of teaching. Often students are not receptive to information because they do not see its importance or because they have attitudinal or emotional biases. In such situations discussion may be the most effective way of developing a readiness to learn.

Rarely, however, does one find a college teacher who admits that he is primarily teaching facts. Almost invariably we couch our objectives in terms of loftier terms like "understanding," "critical thinking," "intellectual curiosity" or, somewhat more prosaically, "application." But whenever we state these higher level objectives we incur an obligation to examine what teaching methods can best achieve them. One candidate is the discussion method.

In addition to the intellectual changes that occur in students, most professors have some explicit or implicit motivational or attitudinal goals. We'd like our students to leave the course with a livelier interest in the area in which we teach; we hope that our students will be motivated to do additional reading, or even to take another course in the same field. Often we'd like to change more general attitudes such as their attitudes toward science or toward engineering. For these objectives, too, some forms of discussion teaching are particularly well suited.

A Theoretical Basis for Discussion Technique

Why should discussion be the method of choice when we have the objectives listed above? To answer this let us examine psychological theory relevant to classroom learning.

Motivation

Student learning and memory is closely tied to *motivation*. Students learn what they want to learn and have great difficulty in learning material in which they are not interested. Much as we would like to teach only students who are eager to learn, most of us have to recognize that not all students are deeply interested in everything we like to teach.

One of our primary problems, then, is motivating students. Usually the learning psychologist stops with this point, but to be useful such a concept needs to be paired with information about dependable motives of college students. We know, for example, that most of our students are taught by their parents to want to do well in school. Thus we can count on some motivation for achievement, and to this extent lecturing and assigned readings can be useful teaching methods.

We know, too, that most of our students *want to be liked*. This motive may work against us as well as for us. In a discussion the teacher's *friendly approval* can be an important reward for learning, but at the same time the "average raiser" or the bright student who always knows the answers is not always well-liked. Thus students who want acceptance by their classmates may avoid any conspicuous display of academic achievement. Many students suffer from real conflict between the need to get good grades and the need to be well liked. One of its symptoms is the ostentatious neglect of study by some bright students and their apparent surprise when they get good grades. This ploy is so well known that its techniques have been analyzed carefully by Stephen Poster in his scholarly volume, *One-upmanship*.

Many of our students have conflicting motives. One common conflict is between independence and dependence. This means that students are likely to resent the teacher who directs their activities too closely but they also are likely to be anxious when given independence; so that we have the neat trick of finding ways of simultaneously satisfying both needs. As a result of this conflict some students disagree with the teacher not from any rational grounds but simply as a way of expressing emotions. The discussion leader may be made uncomfortable by such negativism but at least is more likely to be able to deal with it than the instructor who pushes ahead without awareness of student resistance.

All of us could list many more common student needs. My point, here, is simply that these provide the tools by which we get learning to take place, and as far as speed of learning is concerned, it doesn't seem to matter much which motives you use--the important thing is that motivation exists and that conflicts not be activated.

If this be so, let us consider the case of our most important motivational device--grades. Whatever a student's motivation for being in college, grades are important to him. If he is really interested in learning, grades represent an expert's appraisal of his success; if he's interested in getting into professional school, good grades are the key which will unlock graduate school doors; if he wants to play football, grades are necessary for maintaining eligibility. Most students are motivated to get passing grades, and much as we resent record keeping, the grades for which we're responsible are a powerful motivational tool.

Most of us are a little embarassed by this. We regard grades as one of the necessary evils of teaching. We try to discount grades in our discussion of the organization of the course, and try to arrive at grades in such a way that we can avoid trouble with disappointed students. But we frequently fail to use grades to bring about the sort of learning which we desire.

Because grades are important to students, they will learn whatever is necessary to get the grades they desire. If we base our grades on memorization of details, students will memorize the text. If they believe our grades are based upon their ability to integrate and apply principles, they'll attempt to do this. But because grades typically are based on knowledge of facts, students in discussion groups are likely to become impatient with the apparent slowness of progress and their lack of ability to pin down specific answers to probably test questions. The instructor's tests may reinforce their feelings that the discussion hasn't helped them learn what they needed to get their desired grades. If so, he shouldn't be surprised if he detects negative notes in the discussion.

A good deal of evidence has accumulated to suggest that negative and positive motives affect behavior differently. In teaching we usually use mixtures of positive and negative motives. When negative motives predominate, students will work hard, but only if this is the only way to avoid undesirable consequences. If there are ways out of the situation, they'll take them. The result frequently is that students do the least they can get away with.

The striking difference in behavior between the student motivated by fear and the student motivated by hope is illustrated in their behavior during examinations. A study by Atkinson and Litwin (1960) showed that students who were high in anxiety about tests were among the first to complete the course examination and tended to do more poorly on the examination than in their work during the course. Students with positive motivation to succeed tended to stay in the examination room longer. Note that this illustrates the tendency of the fearful person to avoid the situation which arouses his anxiety. Such avoidant, irrational behavior may also occur in recitation or discussion classes which are conducted with sarcasm or in a heavy climate of criticism.

To sum up thus far: motivation is important in learning. We can use student motivation for success, approval, etc., to produce learning. Grades are important incentives for many kinds of motivation. Thus it's important to make sure that grades not be separate from the kind of learning we are using discussion to achieve. Using grades chiefly as a threat may produce avoidance rather than interest.

Organization

A teacher's job isn't done when he interests his class, for the amount students learn depends upon the amount he teaches, and this is not so simple as it may at first appear. It may well be that the more we teach the less our students learn! Several years ago several of our teaching fellows were arguing furiously about how to teach the nervous system. One group argued that since students wouldn't remember all of the details, we might better omit them and teach only the basic essentials which we wanted everyone to learn. Another group argued that students would forget much of what they learned, "But," they said, "If they're going to forget a large percentage, we need to teach much more than we expect them to remember. Otherwise they'll forget even the important things."

To a psychologist such an argument is simply an invitation to an experiment and consequently the combatants agreed that they'd try out their ideas in their own classes, and compare the results on the final exam questions covering the nervous system. The outcome was clear. The students whose instructor had omitted details were clearly superior to those whose instructor had given them the whole story. This result would not have been surprising to David Katz, (1950) the Swedish psychologist who devised a number of unique experiments demonstrating that beyond a certain point adding to the elements in an intellectual task causes confusion and inefficiency.

Fortunately, teaching is an area where you can have your cake and eat it too, for it is possible to teach more and have it remembered better. The magic formula is "Organization." As Katona (1940) demonstrated in a series of experiments on organization and memory, we can learn and remember much more when our learning fits into an organization. If I give you a series of numbers chosen at random, like 73810547 and ask you what the fourth number was, you probably have difficulty remembering, but if I give you the numbers 12345678 you can remember immediately what the fourth number was. Teaching which helps students find a framework within which to fit new facts is likely to be much more effective than teaching which simply communicates masses of material in which the student can see no organization. The successful teacher is one whose students see meaningful problems. The ideal class would begin with a problem which is so meaningful that the students are always just a step ahead of the teacher in approaching a solution.

One of the difficulties in discussion teaching is that the organization is sometimes not clear to the students. Comments are thrown in hit-and-miss and there is no sense of progress toward a solution. One of the advantages of using discussion with advanced students is that they are likely to have an organized conception of the topic into which they can fit the ideas occurring in the discussion. Where students lack such a frame-of-reference, the instructor may need to play a more active role in guiding and summarizing the discussions.

Verbalization

How can we help students develop principles and concepts which they can apply much more broadly than to answer a problem requiring only a memorized answer? All teachers have been disheartened by having a student answer a routine problem perfectly and then fail to use the same knowledge in solving another problem where it is relevant. There have been a number of educational attempts to solve this problem. One of the early slogans was, "Learning by doing." The theory of "learning by doing" was that if one learned something in the situation where the learning was to be used one wouldn't have the added step of learning when to apply it. This is perfectly reasonable, and even makes sense psychologically. The only problem is that the number of situations in which one must use knowledge is infinite. If each human being had to learn everything by doing it himself, we would still be in the Stone Ages. Our whole civilization is based on the fact that man can use words to short-cut the long process of learning by trial and error. Direct experience may be useful at certain stages of learning. If we are to learn to apply a principle in new situations, we need to develop it from experiencing specific instances in varying contexts. But *verbalization* can help us identify the common elements in these situations and shorten the learning process. In fact recent research suggests that even such a complex skill as learning to solo an airplane can be learned in a much shorter air time if the learner practices the skill mentally and verbally. Discussion, of course, provides opportunity for such verbal practice. Here again, however, one would guess that the process of learning can be speeded-up if generalizations are made explicit rather than completely left to individual intuitions.

Active Learning and Feedback

If we expect students to learn skills, they have to practice, but practice doesn't make perfect. Practice works if the learner *sees the results* of his practice, i. e. if he gets "feedback." A number of experiments demonstrate that *active* learning is more efficient than passive learning. One reason for this may be the improved opportunities for feedback in active learning. Discussion techniques may help develop critical thinking because students do the thinking and there is an opportunity to check their thinking against others. But one of the dangers of "student-centered" or "non-directive" discussions is that the results are not apparent. Students may make comments, express opinions, and participate actively, but this doesn't guarantee that their opinions are any more informed at the end of a semester than they were at the beginning. Not all feedback has to come from the instructor--students can learn much from other students or from books--but in order to learn, students need to test out their ideas in a situation in which they can get the results of the test.

However, we need to go a step beyond our principle that students learn what they practice with knowledge of results. It's not always easy to get a student to practice critical thinking. After all, why stick out your neck? The student who remains quiet avoids the risks of disagreement, criticism, and embarrassment. To develop critical thinking, the student must learn to want to think.

This brings us into a third category of goals of education--developing interests, changing attitudes, creating motivation. There are many ways to do this. If we want to develop an interest in thinking we have to make it satisfying. A smile, a nod of encouragement, an excited, "Good. Let's follow that idea through"--these are the tools that we can use, not only to provide feedback, but also to develop the motivation to continue intellectual activity. To develop motivation we need to pose problems that are within the range of our students' abilities. Studies of the development of achievement motivation in children indicate that parents develop this motivation by encouraging the child to do well and setting standards which the child can achieve. Other parents who orient their children toward achievement fail because they set unreasonable goals. Both for the purposes of motivating students for critical thinking and for developing the ability to think critically, experience in solving problems within the student's ken is essential. This by no means implies that the student should never experience failure or criticism, but it does mean that he should be faced with problems which will, more often than not, be soluble. Problems chosen for discussion should thus be ones which permit progress toward a solution.

One of the misconceptions of educators who have recognized the importance of motivation is that they've stopped with the motives students already have. Teachers have assumed that students will learn only those things in which they're interested. Some discussion leaders have used this as an excuse for simply turning students loose to discuss whatever interested them. But a student's motives are not fixed. He can learn new motives. We can teach students to enjoy learning for its own sake. While we must make use of existing motives to create initial satisfactions in learning, we need not be limited by them. By posing challenging but soluble problems, by capitalizing on present interests to lead into new areas, by helping students become aware of their progress - the discussion leader can create motivation for learning.

Lecture vs. Discussion

College teaching and lecturing have been so long associated that when one pictures a college professor in a classroom, he almost inevitably pictures him as lecturing. The popularity of the lecture method probably derives from a conception of the instructor's primary goal as transmitting knowledge. Before reviewing the research on the relative effectiveness of lecture and discussion, let us briefly review their advantages and disadvantages in terms of the concepts presented above.

Since lectures typically provide few opportunities for students to respond, there is little opportunity for students to receive feedback except through periodic tests. However, delay of feedback may not be a major factor in learning knowledge if the learner is motivated and the material is not too difficult. We would, however, expect lack of feedback to be a greater handicap if the lecturer's goal is to develop concepts or to teach problem solving skills. With these latter goals there is experimental evidence that active participation on the part of the learner is more effective than passive listening or observing. Consequently the passive role of the student in the lecture would be expected to be a handicap in achieving these objectives.

Since discussion offers the opportunity for a good deal of student activity and feedback, it could, according to theory, be more effective than lecture in developing concepts and problem solving skills. However, since the rate of transmission of information is slow in discussion classes we would expect lecture classes to be superior in attaining this objective. However, we should point out that not all information must come from the instructor and, in addition, not all information is eagerly received. When information encounters intellectual or emotional resistance, discussion methods may be necessary in order to bring the source of resistance to light where it may be treated.

Moreover if we are trying to achieve application, critical thinking or some of the higher level cognitive outcomes, it seems reasonable to assume that students should have an opportunity to practice application and critical thinking and to receive feedback on the results. Group discussion provides an opportunity to do this. While teaching machines and mock-ups may also be programmed to provide prompt and realistic feedback, a group discussion permits presentation of a variety of problems enabling a number of people to gain experience in integrating facts, formulating hypotheses, amassing relevant evidence, and evaluating conclusions. In fact the prompt feedback provided by the teaching machines may actually be less effective than a method in which students are encouraged to discover solutions for themselves (Della-Piana, 1956).

Since problem solving ordinarily requires information we might expect groups with less background to benefit less from discussion than groups with more background. Some pretty remote support for this hypothesis is provided by a study of learning of children in visits to a museum. Melton, Feldman, and Mason (1936) found that lectures were more effective than discussions for children in grades 5, 6, and 7, but discussions were more effective than lectures for eighth graders.

Unfortunately although there have been many research studies of the lecture method as compared to discussion or other methods, few have used independent measures of these different types of outcomes. The results of the experimentation are generally in line with our hypotheses but are certainly not conclusive.

For example, using tests of information both Remmers (1933) and Spence (1928) found slight but non-significant differences favoring learning in large lecture groups as compared with that in small recitation sections. Ruja (1954) also found that the lecture was superior to discussion as measured by a test of subject matter mastery in a general psychology course. In the other two courses in his experiment there were no significant differences in achievement, nor were there differences in changes in adjustment in any of the courses. Eglash (1954), however, found no difference between a discussion class and lecture class, not only in scores on the final examination in the course, but also in scores on an achievement test administered several weeks after the course had ended. Husband (1951) also found no significant difference in achievement of students in large lecture versus those in small recitation classes. In all of these experiments, the information measured by the examination could be obtained from a textbook. In one of the earliest such comparisons Bane (1925) found no difference between lecture and discussion on measures of immediate recall but a superiority for discussion on a measure of delayed recall.

Hirschman (1952) compared the effectiveness of presenting material by dictation with that of presenting written materials followed by discussion and reading, using a measure of concept learning. The results showed that the reading-discussion method resulted in superior ability to identify examples of the concepts presented. Barnard (1942) compared the effectiveness of a lecture-demonstration teaching method with that of a problem solving discussion. In this experiment the lecture-demonstration method proved superior on a test of specific information but the discussion method was superior on measures of problem solving and scientific attitude. Other evidence favoring discussion was the experiment of Elliott (Beardslee, Birney, and McKeachie 1951) who found that students in his discussion groups in elementary psychology became interested in electing more additional courses in psychology than did students in a large lecture. Similarly Casey and Weaver (1956) found no difference in knowledge of content but superiority in attitudes (as measured by the Minnesota Teacher Attitude Inventory) for small group discussions as compared to lectures.

Distribution of Lecture and Discussion Time

Many universities and large colleges use a method of distributing class meetings between lectures and discussions. This administrative arrangement is supported by a study in the teaching of psychology, in which discussion meetings were substituted for 1/3 of the lectures. (Lifson et al, 1956). Although there were no significant differences in achievement, as compared with lectures the partial discussion method resulted in more favorable student attitudes which persisted in a follow-up study two years later. Warren (1954) compared the effectiveness of one lecture and four recitations to two lectures and three demonstrations per week. In one out of five comparisons the one-lecture plan was superior. In the others there was no significant difference. Superior students tended to prefer the two-lecture plan while poorer students did not. Similarly, study of New York University student preferences for teaching methods resulted in the finding that most New York University students prefer a combination lecture-discussion method to all lectures or all discussions. Students at Iowa prefer all group discussion or a combination of lecture and discussion to lectures alone. (Becker et al, 1958)

In a course in which the instructors must not only give information but also develop concepts, the use of both lectures and discussions would thus seem to be a logical and popular choice.

Research on Differing Discussion Methods

In discussing the liabilities of lecturing, I mentioned that lectures usually place the learner in a passive role and passive learning is less efficient than active. We would expect discussions to promote more active learning. Bloom and his colleagues at Chicago used recordings of classes to stimulate students to recall their thoughts during class (1953). As predicted, they found that discussion did stimulate more active thinking than did lecture classes. Unfortunately no one has followed this up to see how this active thinking relates to gains in knowledge or cognitive skills.

The idea that discussion methods should help overcome resistance to learning is also difficult to verify. Essentially the argument is that some desired learning encounters emotional barriers which prevent it from affecting behavior. For example, a psychology student may learn that distributed practice is effective, but not change his study methods because his anxiety about grades is so great that he doesn't dare try anything different. In such circumstances experiments on attitude change suggest that the instructor must either bring about changes in underlying attitude and motivation or must change the individual's perception of the instrumental relationship between his belief and his motives. Psychotherapists believe that expressing one's attitude in a non-threatening situation is one of the steps in the process of change. A group discussion may provide such opportunities for expression as well as give opportunities for other group members to point out other instrumental relationships.

In addition, most attitudes influencing learning have some interpersonal antecedents and are stabilized by one's perception of the attitudes one perceives other liked persons as having. Group discussion may facilitate a high degree of liking for the instructor and for other group members. It also permits more accurate assessment of group norms than is likely to occur in other techniques of instruction. Consequently, change may follow.

In fact, while individual instruction would be advantageous for many teaching purposes, the presence of a group is a real advantage in bring about changes in motivation and attitudes. Lewin showed in his classic experiments on group decision (1952) that it is sometimes easier to change a group than an individual.

Discussions range from monologues in which occasional questions are interposed to bull sessions in which the instructor is an interested (or bored!) observer. A good deal of research has attempted to compare the effectiveness of differing discussion techniques.

Student-Centered vs. Instructor-Centered Teaching

The theories of client-centered counseling and of Lewinian group dynamics have led to an increased interest in so called "student-centered" discussion techniques. A wide variety of teaching methods are described by the labels "student-centered," "nondirective," "group-centered," or "democratic," discussion. Nevertheless they have in common the desire to break away from the traditional instructor-dominated classroom and to encourage greater student participation and responsibility. In Table I I have attempted to list some of the ways in which the student-centered method has been supposed to differ from the traditional or "instructor-centered" class.

From the standpoint of theory, student-centered teaching in its more extreme forms might be expected to have some serious weaknesses, at least in achieving lower-level cognitive goals. With the instructor's role as information-giver reduced, his role as source of feedback virtually eliminated, and his opportunity to provide organization and structure curtailed, it is apparent that a heavy burden falls upon the group member to carry out any of these functions which are necessary. We would expect that these functions could best be assumed by groups which not only have some background experience in the academic discipline involved but also have had experience in carrying out these functions.

Participation in discussion gives students an opportunity to gain recognition and praise which should, according to theory, strengthen motivation. Some support for this idea comes from Thistlethwait's (1960) finding that National Merit Scholars check as one of the outstanding characteristics of the teachers who contributed most to their desire to learn, "allowing time for classroom discussion". Other characteristics mentioned included "modifying course content to meet students' needs and interests", "treating students as colleagues", and "taking a personal interest in students." However in line with our earlier discussion of feedback, another trait mentioned was "providing evaluations reassuring the student of his creative or productive potentialities".

The advocates of student-centered or group-centered teaching introduce a category of objectives not usually considered in traditional classes. This is the goal of developing skills in group membership and leadership. The group-centered teacher would often argue that even if group-centered teaching were no more effective than traditional methods in achieving the usual course objectives, it is so important that students learn to work effectively in groups that it may even be worth sacrificing some achievement of other objectives in order to promote growth in this area.

With this as an introduction let us review the experimental attempts to demonstrate the effectiveness of student-centered teaching.

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TABLE I

Dimensions Upon Which Student-Centered and Instructor-Centered Methods May Differ

Student-Centered	Instructor-Centered
Goals	Goals
Determined by group (Faw 1949)	Determined by instructor (Faw 1949)
Emphasis Upon affective and attitudinal changes (Faw 1949)	Emphasis upon intellectual changes (Faw 1949)
Attempts to develop group cohesiveness (Bovard 1951)	No attempt to develop group cohesiveness (Bovard 1951)
Classroom Activities:	Classroom Activities:
Much student participation (Faw 1949)	Much instructor participation (Faw 1949)
Student-student interaction (McKeachie 1951)	Instructor-student interaction (McKeachie 1951)
Instructor accepts erroneous or irrelevant student contributions (Faw 1949)	Instructor corrects, criticizes, or rejects erroneous or irrelevant student contributions (Faw 1949)
Group decides upon own activities (McKeachie 1951)	Instructor determines activities (McKeachie 1951)
Discussion of students' personal experiences encouraged (Faw 1949)	Discussion kept on course materials (Faw 1949)
De-emphasis of test & grades (Asch 1951)	Traditional use of tests & grades (Asch 1951)
Students share responsibility for evaluation (Ashmus & Haigh 1952)	
Reaction reports (Asch 1951)	No reaction reports (Asch 1951)

One of the best known comparisons of student-centered and instructor-centered instruction is that of Faw (1949). Faw's class of 102 students met two hours a week to listen to lectures and two hours a week in discussion groups of 34. One of the discussion groups was taught by a student-centered method, one by an instructor-centered method, and one group alternated between the two methods.

As compared with the instructor-centered class, the student-centered class was characterized by more student participation, no instructor correction of inaccurate statements, lack of instructor direction, and more discussion of ideas related to personal experiences.

Faw's major measure of attainment of objectives was in the intellectual area. Scores on course examinations showed small but significant differences favoring the student-centered method. In the area of his major interest, emotional growth, Faw's method of evaluation was to ask students in the student-centered and alternating classes to write anonymous comments about the class. Generally these comments seemed to indicate that the students felt that they received greater social and emotional value from the student-centered discussion groups than they would have from an instructor-centered class.

A very similar experiment was carried out by Asch (1951). Asch, like Faw, taught all the groups involved in his experiment. Three sections of about 30-35 students were taught by an instructor-centered method. One section of 23 students was taught by a non-directive method, quite similar to that of Faw. However, there were certain differences between Faw's and Asch's experiments. In Faw's experiment both student-centered and instructor-centered classes also spent two hours a week listening to lectures. While Faw doesn't mention grading, one assumes that grades were determined by the instructor on the basis of the course-wide examination. In Asch's experiment students in the student-centered class were allowed to determine their own grades.

Asch's results do not completely agree with Faw's. On the final examination in the course, students in the instructor-centered class scored significantly higher than members of the student-centered class, not only on the objective portion of the test, but also on an essay portion. Note, however, that the student-centered class was specifically told that this examination would in no way affect their grades in the course and the two groups were thus probably not equivalent in motivation.

As measured by the Bogardus Social Distance scale, attitude change in the two sections was not significantly different. However, it is important to note that, as compared with the instructor-centered class, a greater percentage of members of the student-centered class improved in adjustment as measured by the Minnesota Multiphasic Inventory.

Asch's students, like Faw's had a different perception of their achievement from that shown by the course examination. Faw's student-centered class did better on the course examination than the instructor-centered class section but thought they would have learned more if they had been in an instructor-centered class. Asch's students rated the student-centered class higher than the instructor-centered class in helping them to learn the subject matter of the course even though they actually scored lower.

A possible explanation for the contradictory results in these and the experiments to follow may be found in the studies of group cohesiveness and productivity in industry. (e. g. Seashore, 1954) These studies indicate that it is not safe to assume that a cohesive group will be a productive one. Cohesive groups are effective in maintaining group standards, but may set either high or low standards of productivity. Since cohesive groups feel less threatened by management than less cohesive groups, it may be difficult to change their standards. Thus in creating "groupy" classes an instructor may sometimes be helping his students develop strength to set low standards of achievement and maintain them against instructor pressures.

Following the model of Lewin, Lippitt, and White's study (1939) of authoritarian, democratic, and laissez faire group climates, the staff of the University of Michigan's general psychology course set up an experiment using three styles of teaching: recitation, discussion, and group-tutorial. (Guetzkow, Kelly, & McKeachie, 1954) As compared to discussion and tutorial methods, the more autocratic recitation method proved not only to produce superior performance on the final examination, but also to produce greater interest in psychology, as measured by the election of advanced courses in psychology. Furthermore, students liked recitation better than the other methods. The greater gains in knowledge produced by the recitation method fit in with the general principle that feedback aids learning, for students in the recitation sections had weekly or semi-weekly quizzes. McKeachie (1951) suggests that the popularity of the method is related to student anxiety about grades which is most easily handled when students are in familiar, highly structured situations.

Another factor in these results may be the inexperience of the instructors involved, most of whom had had less than a year of previous teaching experience. It is possible that skillful discussion or tutorial teaching requires greater skill than more highly structured methods.

One of the most comprehensive experiments on student-centered teaching was that of Landsman (1950). Landsman experimented with a student-centered type of teaching as contrasted with a more direct type of democratic discussion organized around a syllabus. His experimental design involved eight classes in a course sequence of "Human Development," "Adjustment," and "Learning." Three instructors took part in the experiment, and each instructor used both methods. Outcome measures included the Horrocks-Troyer test (an analysis of case histories) a local case history analysis test, personality test, autobiographies, and students' reactions. His results showed no significant difference on any of the measures between methods.

A number of other experiments have also been carried out with negative results. For example, Johnson and Smith (1953) also found no significant difference between "democratic" and lecture classes in achievement test scores. An interesting side light of their experiment was that one democratic class gave the class extremely favorable evaluations, while the other democratic class tended to be less satisfied than lecture classes. Bills (1952), Maloney (1956), Slomowitz (1955) and Deignan (1955) also found no difference in achievement but did find greater student satisfaction in classes taught by student-centered methods.

The Johnson and Smith study is one of the few to provide evidence relevant to our earlier suggestion that the success of student-centered teaching depends upon the previous group experience of the students. They suggest that the critical factor in making their successful democratic class go, was the enthusiastic participation of a member of a student cooperative.

Wispe (1951) carried out an interesting variation of the student-centered versus instructor-centered experiment. Instead of attempting to control the instructor-personality variable by forcing instructors to teach both instructor-centered and student-centered classes, Wispe selected instructors who were rated as naturally permissive or directive and compared their sections of the Harvard course in "Social Relations." He found no difference in final examination scores between students taught by different methods. Students preferred the directive method and the poorer students gained more in directive classes.

As a counterpoint to Wispe's study we have Haigh & Schmidt's experiment (1956) in which students were given their choice of group-centered or instructor-centered teaching. The results showed no difference in the achievement of the two groups on a non-graded test.

One of the few studies supporting instructor-centered teaching is that of Burke (1956). In a freshman orientation course he found student performance in classes of 125 to be superior to that of students in 4-7 men cooperative groups. Moreover, this difference generalized to other courses. On the other hand Moore and Popham (1959) report that three student-centered interviews with students produced greater gains on the College Inventory of Academic Adjustment than did three content-centered interviews conducted outside of class in an educational psychology course.

While scores on the objective final examination seems to be little affected by teaching method, there are, in addition to the changes in adjustment reported by Asch, Faw, and Moore and Popham other indications that student behavior outside the usual testing situation may be influenced in the direction of educational goals by student-centered teaching. The classes compared by Bovard (1951) and McKeachie (1951) differed in the degree to which interaction between students was encouraged and in the degree to which the class made decisions about assignments, examinations and other matters of classroom procedure. Like other experimenters, Bovard and McKeachie found that the groups did not differ in achievement measured by the final examination. However, clinical psychologists evaluated recordings in the class discussion which followed the showing of the film, "The Feeling of Rejection." Both clinicians reported that the "group-centered" class showed much more insight and understanding of the problems of the girl in the film.

Similarly Patton (1955) felt that an important variable in group-centered classes was the students' acceptance of responsibility for learning. In his experiment, he compared traditional classes to two classes in which there were no examinations, no lectures, and no assigned readings. Students in the experimental classes decided what reading they would do, what class procedure would be used, what they would hand in, and how they would be graded, so that they had even more power than had the experimental groups reported above. At the end of the course, these classes, as compared to the control group, (1) felt that the course was more valuable, (2) showed greater interest in psychology; and (3) tended to give more dynamic, motivational, analyses of a problem of behavior.

But giving students power can't work if students will not accept responsibility, so Patton also obtained individual measures of acceptance of responsibility within the experimental classes. As hypothesized, he found that the degree to which the student accepted responsibility was positively correlated with gain in psychological knowledge, gain in ability to apply psychology, rating of the value of the course and interest in psychology. Thus the effect of giving students additional responsibility seemed to depend upon the student's readiness to accept that responsibility.

Opposed to Patton's overall results are those of Smith (1954) who found no differences between three methods varying in degree of directiveness as to their affects upon students' abilities to make "applicational transfer" of their learning.

Similarly Krumboltz and Farquhar (1951) found that students were least highly motivated by a student-centered method as compared with instructor-centered and eclectic methods of teaching.

The most impressive findings on the results of small group discussion come from the research on the Pyramid Plan at Pennsylvania State University carried out by Carpenter and Davage (1959). The basic plan may be represented by experiments in psychology. Each Pyramid Group of psychology majors consisted of six freshmen, six sophomores, two juniors, who were assistant leaders, and a senior who was group leader. The group leaders were trained by a faculty supervisor. One control group consisted of students who simply took pre-test measures; another control group received comparable special attention by being given a special program of lectures, films, and demonstrations equal to the time spent in discussion by the Pyramid groups. The results on such measures as attitude toward psychology, knowledge of the field of psychology, scientific thinking, use of the library for scholarly reading, intellectual orientation and resourcefulness in problem solving were significantly favorable to the Pyramid plan. Moreover a follow-up study showed that more of the Pyramid students continued as majors in psychology. Such an array of positive results is little short of fantastic, and is not only a testimony to the effectiveness of the Pyramid program but also to the resourcefulness of the Pennsylvania State research staff.

Gibb and Gibb (1952) have reported that students who were taught by their "participative-action" method were significantly superior to students taught by traditional lecture-discussion methods in role flexibility and self-insight. In the participative-action method class, activities centered around "sub-grouping methods designed to increase effective group participation." "The instructor, who played a constantly diminishing role in the decisions and activities of the groups, gave training in role playing, group goal setting, problem centering, distributive leadership, evaluation of individual performance by intra-group ratings, process observing, and group selection, evaluation and revision of class activities." Gibb and Gibb also provide support for the assumption that group-centered teaching can facilitate development of group-membership skills. They found that in nonclassroom groups the participative-action students were rated higher than other students in leadership, likeableness, and group membership skills.

Although McKeachie (1954) reported significant changes in attitude of students toward Negroes and toward treatment of criminals, differences between leader-centered and group-centered classes were not significant. However, group decision did, as predicted, produce more accurate perception of the group norm and more conformity to the norm than lecture or discussion without decision. While no direct attempt was made to change the group norm, the experiment would suggest that the instructor who wishes to change attitudes might find the group decision technique useful.

One final bit of support for the less directive teaching is Thistlethwait's finding (1959) that there is a significant negative correlation between college productivity of Ph.D's in natural science and its students' acceptance of the statement "Instructors clearly explain the goals and purposes of their courses." Such studies of National Merit Scholars are shocking to conventional theory. Most psychologists have thought that prompt feedback and well-structured sequences of presentation were conducive to learning. Yet the Thistlethwait studies indicate that the top colleges in production of scholars are ones where tests are infrequent and where students don't know what to expect next. If this is so, maybe we need to throw some random elements into our lectures and teaching machines. In any case, it suggests that techniques most suitable for learning knowledge may not be those most effective for developing motivation and high level achievement.

Student-Centered Teaching: Conclusions The results of the spate of research on student-centered teaching methods are not impressive, but tend toward support of the theory with which our discussion began. We had suggested that student-centered teaching might be ineffective in achieving lower-order cognitive objectives. There seem to be few instances of such a loss. Students apparently can get information from textbooks as well as from the instructor. The possible advantage of student-centered instruction in achieving the goal of application of concepts is supported by the experiments of Bovard and McKeachie, Patton and Carpenter. The theory that student-centered teaching is effective in producing non-cognitive changes is supported by the experiments of Popham and Moore, Faw, Asch, and Gibb and Gibb. Finally, the only experiment in which group membership skills were measured (Gibb and Gibb) did find the group-centered students to be superior.

Factors Affecting Effective Discussion Teaching

Buzz Sessions One of the popular techniques for achieving student participation in small groups is the buzz session. (McKeachie, 1956b) In this procedure, classes are split into small sub-groups for a brief discussion of a problem. Although many teachers feel that this technique is valuable as a change of pace or as a way of getting active thinking from students, little research has tested its effectiveness. Vinacke (1957) found that as compared with performance on a pre-test, students in two-and three-man groups wrote more new ideas after a five-minute discussion than did students working alone. However it is possible that similar changes could have been produced by a general discussion or a lecture.

Leadership Laboratory and field studies of group processes may shed some light on factors which condition the effectiveness of groups and which thus may help account for the lack of effectiveness of many discussion classes. For example, one of the problems faced by the discussion leader is the student who dominates discussion or the clique who carry the ball. It may be that in some discussion classes, our fear of exerting too much control over the class may have resulted in failure to insure that minority points of view were given an adequate hearing. Research suggests that effectiveness of group problem solving depends upon the leader's ability to obtain a hearing for minority opinion. (Maier & Solem, 1952)

Some student-centered teachers have assumed that all decisions should be made by the group. Hence the instructor should not determine objectives, make assignments, or give tests, but should ask the group to make these decisions. If the group does this, can the time lost from academic work in making decisions be compensated for by the increased motivation of the students? Democratic methods permit the formation of group norms and accurate perception of group norms, but as in industry these norms may not necessarily be conducive to high productivity or learning. The general question of the areas in which the instructor should make decisions is one which different instructors have answered in different ways, and one well worth further discussion and research. One hunch based on research on business conferences is that the instructor should make most procedural decisions, leaving the class time for problems related to the content of the course (Heyns 1952).

Studies of business conferences have found that one of the most common causes of dissatisfaction is the member's failure to understand the purpose of the conference. When students have confusion about purposes of teaching procedures and this is coupled with the stress involved in getting a good grade, it's little wonder that the student with a high need for achieving success is frustrated and often aggressive in a democratic class. Bloom's studies of student thought processes in Chicago classes show that on the average 30% of the student's time in discussion classes is spent in thinking about himself and other people compared with 18% of the time in lectures. With members of the group thus concerned about their own needs, it is no wonder that discussion groups are not always productive.

Even in discussion of course content, however, it appears that some instructor direction may be useful if the goals are learning of relationships and the ability to apply the learning. In an experiment comparing groups given more vs. less instructor direction in discovering the basis of solutions of problems, Craig (1956) found that the directed group not only learned faster but retained their learning better than the group given less help. This result is supported by Corman's research on guidance in problem solving (1957)

Grading Another important problem in conducting student-centered or other discussion classes is that of grades. Not only does the instructor control the pleasantness or unpleasantness of a good many student hours, but because of his power to assign grades he can block or facilitate the achievement of many important goals. The importance of this aspect of the teacher's role is indicated by studies of supervision in industry. In one such study it was discovered that workers were most likely to ask a supervisor for help if the supervisor did not have responsibility for evaluating his subordinates. (Ross 1956) This implies that as long as students are anxious about the grades the instructor will assign, they are likely to avoid exposing their own ignorance.

The student's anxiety about grades is likely to be raised if his instructor's procedures make him uncertain about what he must do in order to attain good grades. For many students democratic methods seem unorganized and ambiguous. In an ordinary course the student knows that he can pass by reading assignments and studying lecture notes, but in a student-centered class he is in a course where the instructor doesn't lecture, doesnt't make assignments, and doesn't even say which students comments are right or wrong. The student simply doesn't know what the instructor is trying to do.

Some instructors have thought that the grade problem might be licked by using a cooperative system of grading. Deutsch (1949), found no differences in learning between students in groups graded cooperatively and those graded competitively, although the cooperative groups worked together more smoothly. Following up Deutsch's work, Haines (1959) found no significant achievement advantages for students working cooperatively vs. those working competitively for grades, but did find marked differences in group morale. Haines's work suggests that cooperative grading in the discussion can be successfully combined with individual grading on achievement tests. However in an experiment in which a "teamwork" class using group incentives was compared with a lecture class Smith (1955) did not find differences in satisfaction comparable to those of Haines and Deutsch.

Complicating the problem of grading is the probability that low grades produce different effects upon different students. Waterhouse and Child (1953) found that frustration produced deterioration in performance for subjects showing high interference tendencies but produced improved performance for those with low interference tendencies.

Considering the importance of grading for both students and instructors, it is regrettable that there is so little empirical research. How do students learn to evaluate themselves? How do they learn to set goals for themselves? Do differing grading procedures facilitate or block such learning? To these questions, we have no answers.

Size of Discussion Groups

One of the earliest experimental studies on college teaching was that of Edmonson and Mulder (1924) on class size.

This study was conducted in an education course in which there were two sections--one of 45 students, the other of 109. Both sections were taught by the same instructor in order to control the possible effect of instructor differences, and both sections used the same text and had the same tests. The method of teaching used in each section was discussion. Forty-three students in each class were paired on the basis of intelligence and past experience. This pioneer study led to the conclusion that size of class is not a significant variable in effective student learning as measured by usual course achievement tests, although students preferred the small classes. (If 45 can be considered a small discussion group!)

There seems to be little theoretical reason for the choice of the sizes represented in the experiment and there is some doubt as to whether either size is optimal for discussion. However similar results are reported by Hudelson (1928) using classes of 20 and 113, and by Brown (1932). In fact using special team procedures Brown produced slightly better achievement in groups of 60 than were obtained from discussion classes of 25.

Support for small classes however comes from the studies in the teaching of French conducted by Cheydleur (1945) at the University of Wisconsin between 1919 and 1943. With hundreds of classes ranging in size from 9 to 33, Cheydleur found a consistent superiority for the smaller classes. Mueller (1924) found similar results in an experiment comparing elementary psychology classes of 20 and 40 students. A study by Schellenburg (1959) suggests that even the smallest groups in these studies may be above optimal sizes. Working with discussion groups of 4, 6, 8, and 10 students he found higher satisfaction and higher instructor grading in the smaller groups. While Schellenburg recognizes that grades are an unsatisfactory criterion since the instructor's judgment may shift from section to section, he refers to laboratory studies of group problem solving which point to optima in the area of 4-6 person groups.

From the standpoint of theory, increasing size would be expected to increase the resources of the group but decrease the group's ability to exploit its total resources. With increasing size there is not only less time for each member to speak but there is also an increasing reluctance to participate (Gibb 1951). In larger groups discussion is usually increasingly dominated by a few people (particularly the instructor). Thus group size is probably much more important in effecting the success of discussion than it is for lectures.

Homogeneous vs. Heterogeneous Grouping One of the common criticisms of discussion classes is that class time is wasted either by discussion of problems raised by the able students which are beyond the ken of the other students or by problems raised by poor students which the other students feel are too elementary. One answer to such criticism is to use homogeneous groupings so that each student is discussing problems with other students of his own ability.

Recently concern about America's resources of high level talent has resulted in the proliferation of Honors Programs featuring such homogeneous classes for students with high academic aptitude and achievement. While the logic of such programs is evident, there is little research evidence that they are of educational value. In fact, one of the earliest college experiments on ability grouping showed no significant advantages for homogeneous grouping and even a trend toward the opposite result in classes in psychology. (Longstaff, 1932).

Homogeneous grouping by personality proved to be ineffective in the experiment in group problem solving reported by Hoffman (1959). Comparing groups of four students who were similar in personality to groups made up of dissimilar students, he found that the heterogeneous groups produced superior solutions. Hoffman accounts for this difference by suggesting that heterogeneous groups are likely to have a variety of alternatives proposed and this permits inventive soluations.

On the other hand, in a study by Stern and Cope (Stern, Stein & Bloom 1956), groups of "authoritarian," "antiauthoritarian," and "rational" students in a Citizenship course were segregated into homogeneous groups in which the instructor was unaware of the particular group which he was teaching. Authoritarian students in the experimental group achieved more than comparable authoritarians in conventional classes.

It is apparent that we need further analysis of what kinds of homogeneities or heterogeneities contribute to what objective. If we omit from consideration general adjustment problems of segregated groups, the idea that one should be able to do a better job of teaching to a group of known homogeneous characteristics than to a heterogeneous group seems so reasonable that it is surprising to find little research support. It may be that the potential advantage of carefully planned grouping has not been realized simply because we haven't yet learned optimal teaching procedures for such groups.

Skills in Discussion Teaching

Consideration of the theory and research relevant to discussion teaching has already pointed to a number of techniques of teaching by discussion.

Before reviewing these skills, it should be pointed out that there are many varieties of discussion. Some discussions primarily involve group problem solving; others are gripe sessions; others may be pep meetings. Each of these is useful in its place, and the instructor's role will obviously depend upon which of these types of discussion he is leading. In classrooms, however, the most commonly used discussion method is probably developmental discussion, and this section will primarily be concerned with this method.

What is "Developmental Discussion"?

Like other discussion methods, developmental discussion implies active participation of group members. In developmental discussion, participation is directed to a definite goal such as solution of a problem and the leader takes an active role in helping the group progress toward the goal. However, this does not imply a type of discussion leadership in which the leader manipulates the group to follow the steps and reach a goal which he has pre-determined. Rather his leadership helps the group progress by dividing the problem up into parts which can be solved in steps. In short, developmental discussion is not non-directive but neither is it autocratic.

Skills in Leading Developmental Discussion

In a developmental discussion the teacher attempts to guide a discussion along a certain line, but not to push it beyond the group's interest and acceptance. Obviously this requires skill in initiating discussion, appraising group progress, asking questions, and overcoming resistance.

Starting Discussion

After a class has been meeting and discussing problems successfully there is little problem in initiating discussion, for it will develop almost spontaneously from problems encountered in outside reading or experiences or from continuation of discussion of unresolved problems of the previous meeting. But during the first meetings of the new groups the instructor may need to assume the initiative in beginning the discussion.

One of the best ways of starting a discussion is to provide a concrete, common, experience through presentation of a demonstration, film, or role playing. Following such a presentation it's easy to ask "Why did ----?"

Such an opening has a number of advantages. Since everyone in the group has seen it, everyone knows something about the topic under discussion. In addition, by focusing the discussion on the demonstration, the instructor takes some of the pressure off anxious or threatened students who are afraid to reveal their own opinions or feelings.

The typical instructor, however, will not always be able to find the demonstration he needs to introduce each of his discussions. Thus he will be forced to turn to other techniques of initiating discussion. The most commonly used is the question.

The Question

One of the common errors in question-phrasing is to ask questions which obviously have only one right answer which the instructor already knows. As we implied in our treatment of its goals, discussion has little function in determing questions of fact. Rather discussions need to be formulated so as to get at relationships, applications, or analysis of facts and materials. A question of the type "How does the idea that ------ apply to ------?" is much more likely to stimulate discussion than the question "What is the definition of ----?"

A second common error in framing questions is to frame the question at a level of abstraction inappropriate for the class. Students are most likely to participate in discussion when they feel that they have an experience or idea which will contribute to the discussion. This means that the discussion questions need to be phrased as problems which are meaningful to the students as well as the instructor. Such questions can be devised more easily if one knows something of the students' background. An experiment by Sturgis at Georgia Tech (1958) showed that such knowledge of student background makes a significant difference in a teacher's effectiveness as measured by his students' learning.

In posing a problem to stimulate discussion it is important that students feel that the problem has no cut-and-dried answer. The problem may arise from a case; it may be a hypothetical problem; it may be a problem whose solution the instructor knows; it may be a problem which he has not solved himself. In any case it should be a problem which is meaningful to the students and, for the sake of morale, it should be a problem which the students can make some progress on.

A third technique of stimulating discussion is to cause disagreement. Some teachers effectively play the role of devil's advocate; others are effective in pointing up differences in point of view. In either case the instructor should realize that disagreement is not a sign of failure but may be used constructively. When rigid dogmatism interferes with constructive problem solving following a disagreement, the instructor may ask the disagreeing students to switch sides and argue the opposing point-of-view. Such a technique seems to be effective in developing awareness of the strengths of other positions.

Getting Participation

Unfortunately most students are used to being passive recipients in class. To help them become participants we try to create an expectation of participation in the discussion section. We can start to do this in the first meeting of the course by defining the function of various aspects of the course and explaining why discussion is valuable. In addition to this initial structuring, however, we must continually work to increase the students' awareness of the values of participation. Even superficial techniques can contribute. For example, we have found that it is helpful to make our first assignment the writing of a brief life history indicating the students' interests and experiences. These autobiographies help the instructor to gain a better knowledge of each student as an individual, to know what problems or illustrations will be of particular interest to a number of students, and to know whom he can call on for special information. One of the best ways of getting a non-participant into the discussion is to ask him to contribute in a problem area in which he has special knowledge. This technique also may be used to increase the interest in the class discussion of those students who have started their own private bull-session.

The law of effect works here too. Rewarding infrequent contributors at least by a smile helps encourage participation even if the contribution is in error and has to be corrected. Getting to know the non-participant outside of class is also helpful. Calling students by name seems to encourage freer communication. Seating is important too. Rooms with seats in a circle help tremendously.

But none of these variables come close in importance to the attitude of the instructor himself. The wise instructor realizes that participation is not an end in itself. For many purposes widespread participation may be vital; for others it may be less important. Essentially he must try to create a climate in which an important contribution is not lost because the person with the necessary idea did not feel free to express it.

Appraising Progress

As this implies, one of the important skills of the discussion leader is ability to appraise the group's progress and to be aware of barriers or resistances which are blocking development. This skill depends upon attention to such cues as inattention, hostility or diversionary questions.

Skill at appraising is of little avail if the instructor doesn't respond to the feedback he receives. In some cases he may need to respond only by interposing a guiding question or by emphasizing a significant contribution. In other cases he may need to summarize progress, and restate the current issue or point out the stumbling block or diversion which has stopped progress. In extreme cases, he may have to stop the discussion to begin a discussion of the reasons for lack of progress.

Maier and Maier (1957) have shown that problem solving is improved when the discussion leader takes the problem in steps, reaching consensus at each step before proceeding to the next. This technique of breaking a problem into parts not only gives the discussion more focus but also helps students become aware of their progress.

Barriers to Discussion

As we saw earlier one barrier to effective discussion may be inadequate information. The instructor's role than may be to refer students to necessary sources of information, or he may provide the information himself.

One of the primary tasks of the discussion leader is to promote adequate communication between members of the group. When a student's contribution is unclear, the instructor may restate it and have the restatement confirmed or rejected by the student. However, this device should not be used so much that the students begin to feel that they are ventriloquist's dummies.

Occasional summaries during the hour not only help students chart their progress but help smooth out communication problems. A summary need not be a statement of conclusions. In many cases the most effective summary may be a restatement of the problem in terms of the issues resolved and remaining. Probably one of the commonest barriers to good discussion is the instructor's tendency to tell the students the answer or to put the solution in abstract or general terms before the students have developed an answer or meaning for themselves. Of course, the teacher can sometimes save time by tying things together or stating a generalization which is emerging. But all too often he does this before the class is ready for it.

Another barrier to discussion is agreement. Usually we are so eager to reach agreement in groups that the young instructor is likely to be happy that his students are agreeing. But agreement is not the objective of most educational discussions. Students come to class with certain common naive attitudes and values. While the attitudes they hold may be "good" ones, they may be so stereotyped that the student fails to develop an understanding of the complex phenomena to which they apply. The teacher's task is often directed not so much to attitude change as to increased sensitivity to other points of view and increased understanding of the phenomena to which the attitude applies. As we saw earlier, the instructor may sometimes need to assume a role of opposition.

When the instructor opposes a student opinion he must be careful not to overwhelm the student with the force of his criticism. His objective is to start discussion, not to smother it. Thus he must give students an opportunity to take hold and respond to his criticism examining the point of view which was opposed. Above all, the instructor should avoid personal criticism of a student.

Summary

Why use discussion? We have seen that there are many purposes, just as there are many styles of discussion leadership. The research evidence is not conclusive but my best guess is that good discussion teaching is among the most effective methods for developing ability to apply information, for improving problem solving, and for changing motivation or attitudes.

The skills which I have suggested are intended to smooth some of the rough spots in learning to teach by discussion, but good discussion teaching ultimately depends upon the character and values of the instructor. To be successful he must sincerely respect and accept students as fellow human beings engaged with him in the common pursuit of education.

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LEARNING BY DISCUSSION--AN OUTLINE FOR THE INSTRUCTOR

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Introduction

College teaching and lecturing have been associated so long that when one pictures a professor in the classroom almost inevitably the picture is one of a lecturer. Small wonder, though, because so few college teachers receive any orientation or training in teaching methods. Consequently, very likely they resort to copying what they have observed most of their lives as students, namely the lecture. This method might be termed a "comfortable" one for most instructors because it is familiar to them and also because it provides for careful planning in advance, for control over most of every class session, and for a minimum chance of being put on the spot.

Teaching through a discussion method, on the other hand, is less predictable and definite, offers less opportunity for control and, therefore, often feels less comfortable to the instructor. It requires not only considerable restraint but also great skill and much experience to function smoothly, comfortably, and effectively in a discussion session. He must realize that a certain amount of floundering by the participants in group discussions, for example, can be far more meaningful from an educational standpoint than if he were to inject a ready-made, sure-fire answer. He must understand further that a permissive attitude and atmosphere likely will enable much more creative and thought-provoking discussion to take place, that usually it is far better for the group to appraise, accept, or reject ideas of its members, to deal effectively with the talkative one, or to realize that the discussion is digressing and insist that it be brought back on the track. He must appreciate the fact that agendas are not sacred and that spontaneous discussion on a subject of interest and concern to the group may provide them with an opportunity for greater insight and incentive for further study than rigid adherence to some carefully planned and structured program. At the same time, he dare not fall into the trap of insufficient preparation for, although the discussion method places great responsibility on the student, without a set of lecture notes or an outline which will limit what is considered in a given session the instructor must be both broadly and thoroughly prepared and should attempt to anticipate a variety of possible classroom developments. He must seek to overcome the feeling that nothing useful or beneficial is happening unless he is talking. The lecture system appears to be so thoroughly a part of most educational programs that both students and instructors, by and large, often feel that everything depends on the instructor, that unless the instructor is doing something the course is not "moving."

To those who catch the spirit of the system, the discussion method can be stimulating and meaningful and, in the long run, quite useful because the individual through greater insight develops something which he feels he has had a direct hand in developing. That approach can be a difficult one, though, for student, too, because the method likely is counter to many years of formal academic study in classrooms where teacher-dominated courses, structured programs, and directed activities were predominant, and where the student was only rarely and in a limited sense "put on his own." Consequently, the discussion method might be strange, bewildering, frustrating and, frequently, upsetting. It is sometimes difficult for persons so advanced in academic life and experience to comprehend the philosophy of discussion, to understand fully the requirements on them for successful operation of the system, and to feel comfortable or satisfied in a less-directed or less-structured program. The tendency in most educational programs appears to be to look to the instructor and to lean on the instructor: if he does not function, then nothing happens. Hence, for the participants it is important that they be enabled early in the course to ascertain the approach being employed, to learn its philosophy and method of operation, and to realize their individual responsibility in determining the progress and success of the course.

The outline which follows is intended to provide some "how to do it" suggestions to aid the instructor in applying in the classroom some of the principles set forth by W. J. McKeachie in his preceding paper on "Recitation and Discussion."

Basic Characteristics of Discussion

1. Informal group atmosphere should prevail.
    a. Group arranged in circle or hollow square if possible.

  - b. Persons speaking usually address other members of group rather than leader, chairman, or instructor.
  - c. Recognition by chairman seldom needed before speaking.

2. All group members should have opportunity to participate actively.
   - a. Atmosphere of frankness and friendliness should help every participant get into discussion and enjoy it.
   - b. Permissive attitude likely will enable more creative and thought-provoking discussion to take place.
   - c. Occasional silent periods often indicative of thought and silent "participation" rather than activity.
   - d. Participation can be both verbal and non-verbal. Non-verbal participation can be:
     - 1) Nodding agreement, smiling, or frowning to indicate support of ideas, rejection of points of view, and the like.
     - 2) Effective listening for comprehension and understanding of the contributions of others.
   - e. Effective listening permits others to speak.
   - f. Recognition by chairman seldom needed before speaking.

3. All group members should share responsibility for success of discussion.
   - a. Preparation is of paramount importance.
     - 1) Amount of preparation often determinant of success of discussion.
     - 2) Pooling of ignorance cannot result in more than conclusions that reflect that ignorance.
     - 3) Preparation for discussion essentially an individual matter.
   - b. Participation on part of each member of group essential.
     - 1) Participant in discussion does not play a passive role.
     - 2) Participation should be careful, critical, and reflective.
   - c. Cooperativeness ought to be stressed.
     - 1) Individual goals ought to be subordinate, at least during the discussion, to group goals.
     - 2) Effective listening for comprehension and understanding of contributions of others is essential.

   d. Participants should not lean on instructor, or chairman, to direct and/or to "keep things moving."

4. All group members should share responsibility for decisions or conclusions reached.
   a. Role of instructor in these matters must be established clearly from start.
   b. Democratic method should be employed to arrive at group conclusions, if necessary, or decisions.

5. Group unity should be strong.
   a. Important to subordinate individual goals to group goals, at least for duration of discussion.
   b. Cooperativeness ought to take place.
   c. Thinking and verbalization ought to be in terms of "we," "you", "us", rather than "I", etc.

6. Freedom of choice should be stressed.
   a. Group unity does not necessarily mean conformity.
   b. Ideas or decisions may sometimes be shared or integrated.

7. Progress not always orderly, not always sure and definite, often involves trial and error.

The Instructor in Discussion

1. Must be broadly and thoroughly prepared in subject area.
   a. Must study and think in advance, then come prepared to "rethink" with other members of group.
   b. Must attempt to anticipate variety of classroom developments.
2. Should come to the meeting with a feel for the purpose and possibilities of the session.
3. Responsible for opening and closing the session, and for certain physical arrangements.
   a. Should observe time limits.
   b. Should be aware of comfort and other needs of participants.
4. Should set comfortable atmosphere of frankness and friendliness which will help every person get into discussion and enjoy it.

5. Serves as impartial guide or, perhaps, as chairman rather than as active participant.
    a. Should seek to overcome feeling that nothing useful is happening unless he is talking.
    b. Should seek to overcome feeling that nothing useful is happening unless someone is talking.
    c. Should realize that certain amount of floundering by participants can be far more meaningful than if he were to inject ready-made, sure-fire answer.
    d. Should believe that permissive attitude and atmosphere likely will enable much more creative and thought-provoking discussion to take place.
    e. Should understand that often it is far better for group to appraise, accept, or reject ideas of its members, to deal effectively with talkative one, or to conclude that discussion is digressing and insist that it be brought back on track.
    f. Should consider that agendas are not sacred and that spontaneous discussion on a subject of interest and concern to the group may provide them with opportunity for greater insight and incentive for further study than rigid adherence to some carefully planned and structured program.
    g. Should anticipate a variety of possible classroom developments by having readily available reference books, pamphlets, bibliographies, etc.
    h. Should permit silent periods, if they occur, during which thinking can take place, without embarassment or feeling that he ought to "get things moving."
    i. Should speak primarily to reflect feeling; to provide internal summaries, if desirable; or to raise matters, if appropriate, missed by group.
        1) Examples: "What do you think?" "How do you feel about it?" "What has been your experience with....?" "Does anyone have facts about....?" "...or info on?" "What do some of the rest of you think?" Smile; nod of encouragement.

    - 2) Should not feel need or obligation to respond after each contribution.
  - j. Listening is strong factor in good "leadership."
    - 1) Effective listening for comprehension and understanding of all contributions is essential (instructor must pay attention to students!).
    - 2) Good test of understanding is ability to state another person's contribution in such a way that he will accept.
  - k. Should not be upset by displays of hostility or negativism on part of students who demand to be directed and spoon fed.
  - l. Should comprehend fact that it may take many sessions for students to understand method and become adjusted to it.
  - m. Above all, needs patience and restraint.

6. If concerned about:
  - a. Keeping group organized.
    - 1) Good preparation on part of all participants aids organization considerably.
    - 2) Periodic internal summaries help keep group on track and help keep things moving.
    - 3) Injection of a "leading" or "steering" question may help get group back on track and/or moving.
  - b. Person who talks too much.
    - 1) Attempt to bring in others by asking them questions or steering discussion in their direction.
    - 2) Interrupt by brief summary and request for opinions on subject from others.
    - 3) Usually will talk less if seated as far as possible from discussion leader.
  - c. Person who talks too little.
    - 1) Attempt to bring in person by asking direct question of him.
      - a) Should not be question which can be answered simply by "yes" or "no."
      - b) Might be a controversial question.
    - 2) Attempt to steer discussion toward main interest (if known) of person.
    - 3) Usually will talk more if seated close to leader.

d. Conflicts in discussion.
    1) Must remain impartial.
    2) Should attempt to find common ground for agreement, if such procedure is appropriate to particular conflict.
    3) Could suggest ways of settling conflicts (obtain data, consult authorities, re-study of matter, etc.), if such procedure appears appropriate.
    4) Under certain circumstances some sort of majority vote may be appropriate and satisfactory.

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PROJECT INSTRUCTION

Philip Nudd
The Cooper Union

Learning to become creative and productive on a high level of service to society may be accepted as a definition of the objective of education for the professions. Formalized definitions of the engineer invariably stress the creative and productive nature of his activity, and all ASEE studies of his education have emphasized need for strongly oriented learning to develop creative and productive facility.

Learning Characteristic of Engineering Education

Relative ease with which essential factual information may be presented and its retention measured has been recognized as contributing to some degree of neglect of more significant learning. Memorization has long been recognized as the most elementary form of learning. The learner of low intelligence can compete in this activity to a degree not possible in higher forms of learning which involve reasoning. It follows that learning experiences in which receiving and memorizing information is the dominant activity are expected to be non-characteristic of engineering education. The principles of learning indicate that the learner must have continuous experience in creative and productive activity to develop this intellectual capacity effectively, and these learning experiences are expected to characterize engineering education.

A Definition of Project Instruction

The most essential condition for learning demands activity of the learner. He learns what he is thinking, feeling and doing. Effective learning for creative and productive work requires that the learner engage in this activity in a manner realistically related to that in which he is expected to develop facility. Higher levels of such activity in education have commonly been associated with projects, the case method, thesis, and with that magic word of many interpretations now in vogue, research. Since project is the least restrictive term, it will be used here with a broad interpretation.

Need for Sequential Project Instruction

A more extensive application of project instruction than exists in engineering education has been urged in publications of ASEE committees. The existing failure to attain a satisfactory level of creative and productive learning experience is a challenge not to be ignored by the dedicated teacher. This teacher will attempt to create the particular learning situations which permit and encourage the learner to develop his creative and productive capacities. However, it is inconsistent with the principles of learning to expect the learner to fully develop his capacities in a single high-level course. There is need to stimulate an exchange of ideas among teachers on the possibilities for achieving continuous learning experience with the project method. This is the objective here.

A fundamental condition for learning requires sequential experience on progressively higher levels of the capacities to be developed. Much of the strength of the learner's motivation is dependent on his discovery that previously acquired knowledge and skill is inadequate to attain a strongly desired goal. The immediate experience must appear realistically related to the learner's goal and difficulty must be within the range of challenge--above mere repetition and drill, and below the level where the learner becomes discouraged because previous experience is inadequate to permit success without unreasonable exertion. The conclusion follows that effective development of creative and productive capacities through project instruction requires that projects of progressively higher level be introduced throughout the learner's college career.

Scope of Project Dependent on Learner's Maturity

The requirement that an effective project must match the maturity of the learner implies that the concept of what constitutes a project must be as broad as the span of the learner's maturity. It should not be assumed that projects are not effective at the beginning of a course, even of a freshman course. At this point it is possible to anticipate the specious argument that it is necessary to "give" the student some knowledge before he is capable of self-development in a project situation. This argument stems from some such fallacy as the belief that a college student cannot make what is to him a discovery in mathematics because great mathematicians required centuries to develop the logic of mathematics. The argument ignores all previous experience of the learner, and ignores another principle of learning which recognizes that significant progress is made even when the learner's first attempts are clumsy and his discoveries are new and original only to him. The erudite expert who does not recognize this will be a poor teacher.

The concept of what constitutes an advanced learning project is commonly understood. One which falls in this classification was reported by a professor of civil engineering who had only eight students in his senior class and could take advantage of an applied engineering project which presented itself. The state highway department sought estimates from contractors on a section of highway and a proposal for design of a minor bridge. Members of the class prepared proposals, reduced them to a single production, and submitted this to the highway department. The department was sufficiently impressed to invite the class to submit bids on the engineering work. These were also prepared by the class. A project of this scope and realism may seldom be available and may not be desirable when related to a particular learning program. However, this project illustrates realistic practice for the learner and a desirable objective if he has matured through previous project experience to the point where little guidance is required.

Learning experience within the broad interpretation of project instruction may range from two hours of work to the illustration cited above. Some people would prefer to identify projects at the lower end of this scale as problems. There can be no valid objection to this provided the problems used in project instruction are designed as a progressive approach and complement or lead to projects which develop maturity in creative and productive work. The scope of a project which introduces the learner to this type of learning experience must necessarily be adapted to the immaturity of the learner. However, freshmen students can progress through a few short projects to creditable work on projects requiring several hours to develop.

Characteristics of Project Instruction

Over the sequential span of difficulty and complexity required to develop the learner's capacity, project instruction may be identified by particular characteristics. These characteristics differ in nature and degree from those associated with lecture and recitation types of instruction.

The first requirement of an effective project is that it cause the learner to develop a combination of existing information, techniques, and materials in a form which is new and original to the learner. Since the objective is for the learner to progressively develop his creative and productive capacity, the instructor must restrain his tendency to supply information in anticipation of the project assignment, or to give assistance before the learner has had opportunity to respond to the challenge of the project. The learner must discover that some floundering is normal, and develop confidence that orderly procedures will achieve his objective. The implication is that the learner is expected to read his reference text and consult other sources for the information which is to be developed. It is a principle of learning that greatest motivation and efficiency exists if learning is attempted when it is needed. In this respect project instruction displays an advantage over the teaching of prerequisites which are, in theory, to become useful at a remote time.

A second requirement of an effective project is that its development involve a written presentation of several pages. This requires the learner to develop his tools for coordination and reasoning. He must discover that his presentation is not only a valuable medium for communication, but that it is an essential tool in extended reasoning and a record through which he may check his logic. This discovery is not made in a moment, only after experience on progressively higher levels can the learner come to full realization of the power which his developed skill has conferred.

A third requirement of an effective project is that it be reviewed and criticised by the instructor. In addition to the important objective of accelerating learning, the instructor's review reinforces the learner's satisfaction and conveys a degree of social recognition. It is a principle of learning that satisfaction is a powerful stimulant, and is strengthened by group recognition. Consistent with the preceding requirements of an effective project, the instructor's criticism, or group criticism when practical, should direct at least as much attention to the way the learner worked and the style of his presentation as to the technical details of the task. The reason why the presentation did not disclose an existing fallacy or error is of greater import than the correction.

Administration of Project Instruction

When the relative significance and lasting values of the objectives of engineering education are thoroughly understood it may be possible to prescribe the kind and quantity of learning procedures that will be most effective. It is now necessary to be content with an attempt to assure a reasonable balanced learning in those areas most critical to success in engineering. The creative and productive nature of engineering requires that project instruction, which is particularly effective in developing this capacity, should be fully implemented in the educational program.

Project instruction cannot be fully effective at its highest level unless the learner has matured through continuous practice in this activity. No other learning is an adequate substitute for the experiences which have been defined as the essentials of project instruction. Coordination is then necessary to insure that a significant portion of the learner's activity be in project instruction from the beginning of his college career. An early start in project instruction also has an important effect in developing the learner's attitude toward the creative and productive work of engineering.

The essentials of project instruction have sometimes been introduced in an engineering "analysis" or engineering "methods" course for freshman students. Further experience has often been assumed to be adequately provided through a thesis, term papers, or single course projects. Wherever continuity has not been deliberately planned, there has been a tendency toward isolation of experiences which is inconsistent with the principles of learning. Continuity is best assured by planning project instruction as a part of every subject division of the curriculum. This practice has the additional effect of causing every teacher to be always conscious of the creative and productive objectives of engineering education.

When the essentials of project instruction have not been present throughout the college program, engineering departments have partially restored the balance by concentrating on this type of instruction. This has been accomplished at one institution by scheduling all department classes for two to four hours duration, and by using in-class and outside allocated student time for project instruction only. No examinations are given, evaluation being made on the basis of project work submitted. Instructors avoid lectures, hold group discussions to a minimum, and give aid only when this is sought by the student. A primary objective is to bring the student to the point where he can walk his intellectual path alone, without the teacher and without the stimulation of classroom groups. For developing creative and productive capacity, experience has shown this learning situation to be superior to a routine of lecture, class discussion, oral explanation, one-page problems, and examinations. While developing his creative and productive capacity, the learner acquires at least as much lasting information as through instruction which emphasizes imparting information and testing for retention.

Demands on Teacher

An assumption is often made that project instruction is much more demanding of the teacher's skill and time than other forms of instruction. The degree to which this is true depends on interpretation of the teacher's important contribution and on whether the learner's capacity is developed continuously at reasonable and progressively higher levels.

Preparation of projects requires more of the teacher's time than preparation of lectures, but the lecture cannot attain the required objective. Reviewing student's presentation of projects is more demanding than checking short problems, but the short problems cannot attain the required objective. If a continuous and progressive experience is successful in developing the student's skill and attitude, his work can be reviewed much more rapidly than that of the student inadequately skilled in written presentation. If the teacher considers his function is to guide the student in the creative approach to developing projects, and to make the student responsible for detail, there is no need for the teacher to trace through obscure presentations. High standards of workmanship effectively conserve the teacher's time.

Project Instruction Not the Easy Way

Whenever efforts to improve learning are relaxed, instruction drifts into a routine of lecture and examination. This may be taken as evidence of the easy way. The examinations, measuring only those things which can be accomplished in this easy way, may indicate a most successful operation. Suspicion of inadequacy may only be aroused by complaints that students are frustrated when, without previous demonstration of how to proceed, they are faced with necessity to organize, develop, and present a project. These operations, resistant to automation, are the greatest challenge to engineers, teachers, and students. Project instruction must not be ignored until other methods are discovered which develop to comparable levels the creative and productive capacity of the engineering student.

THE USE OF TECHNOLOGY IN IMPROVING INSTRUCTION

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CHAPTER I

THE NEED FOR AUDIO-VISUAL MATERIALS IN TEACHING

In recent years waves of advancing technology have splashed educators everywhere with a new and intense interest in audio-visual teaching methods. It is a fact that the development of audio-visual service centers for teachers from kindergarten to university has been proceeding at only a snail's pace since the day in 1904 when St. Louis inaugurated the nation's first city-wide visual education service program. The pace of development has now quickened into a rush with the dawning realization that horse and buggy methods could not achieve today's educational goals. University teachers have felt the impact of the interest in new methods and have in fact been in the limelight of educational research in trying out the newer technological advancements for teaching.

But a half century of experience with visual first and then audio-visual devices cannot be by-passed by individuals and then assimilated at the flick of a finger in a sudden rush of desire to put the newer devices to work. It needs to be pointed out that successful use of television and automatic machines often depends upon the integrated use of many kinds of teaching materials such as motion pictures, slides, charts and diagrams, magnetic and flannel boards, and apparatus and models to mention just a few. There is doubtlessly no better way to prepare for the efficient teaching methods of the future than to develop competence in using some of the commonly available devices and methods that have been for years and still are important in making teaching effective. And this is just the purpose of this reference material, for in the following pages the wide range of currently available audio-visual materials will be presented, and some fundamental suggestions will be given for their use in an effort to help engineering instructors find greater success in the complex art of teaching.

Definition of Terms

Technology. The title of this paper incorporates the term technology, and it ought to be stressed that technology refers to both machines and the materials to be used with them. Every teacher knows that a motion picture projector is of value only as the projected films change the behavior of viewers in desirable ways. Similarly it is the tape recorded content that makes the magnetic tape recorder-player valuable in the classroom. Even in automatic teaching machines it is the programmed plan for student responses, with or without pictorial and audio-stimuli, that gives the machine its instructional potential. Since technology includes machines and materials it needs to be pointed out that the content of the material determines crucial teaching decisions, and when materials are being prepared by teachers they must be constructed with limitations of the devices in mind, and the content must be assembled in the light of the teaching objective. Therefore instructional technology is an inclusive term with more than mechanical and electronic connotations. It is important therefore to give strong emphasis in this paper to audio-visual materials within the framework of a broad title.

Audio-visual materials. In this discussion, the expression audio-visual materials will refer to those real and vicarious experiences and devices, other than verbal symbols, which are used in the teaching-learning situation. Such materials include field trips, community experiences, demonstrations and role playing; objects, models, mock-ups, exhibits, television and motion pictures; lantern slides (standard and miniature, both photographic and handmade), transparencies for the overhead projector, sound and silent filmstrips, projected flat pictures and other illustrations (opaque projections), micro-projector projections (both slides as well as animate or inanimate specimens), photographic enlargements, text and pamphlet illustrations; magnetic tape recordings, phonograph records; and graphic aids including maps, globes, graphs, charts, posters, diagrams, cartoons; and the so-called automatic teaching machines. Throughout this reference text, the expression audio-visual materials will refer to all of the items listed above.

Instructional materials. The term instructional materials is a broader term than audio-visual materials. It includes in addition to A-V materials such printed materials as textbooks, pamphlets, documentary leaflets and reports, and sheets of special directions for problem-solving. It is readily seen therefore that in terms of technological development it is the range of audio-visual materials with which this paper is concerned.

Competence. The term competence as used repeatedly in this discussion refers to personal adequacy in the teaching-learning situation, that is, capability to accomplish valid teaching purposes. Competence used in this sense denotes effective performance. The writer has been influenced by Chester I. Barnard's definitions of the terms "effective" and "efficient." He pointed out that, "an action is effective if it accomplishes its specific objective aim. We shall also say that it is efficient if . . . the process does not create off-setting dissatisfactions." Competence, when translated into behavior, implies such effectiveness and efficiency. Just how do audio-visual materials and the devices needed for using them serve the teacher? They play a number of well-defined roles that are stated in the subsequent paragraphs.

Roles Played by A-V Materials

Engineering instructors may, if they have the competence, vigor and the local resources at their disposal, be helped by a wide range of audio-visual materials to carry out unique instructional tasks. This assistance to teachers falls under the five fundamental roles*, which, together with a specific example for each from Engineering courses are as follows:

1. Audio-visual materials (see foregoing definition of terms) provide the teacher with the means for extending the horizon of experience. Example: A teacher may "take" his class by means of an appropriate motion picture film to a remote jungle, mine or mountain to observe and evaluate examples of engineering planning and construction. Some A-V materials may thus be a magic carpet for providing needed experiences (vicarious of course, but perhaps extremely close in observational value to the real thing). Particularly

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*This material is adapted from Carlton W. H. Erickson's Administering Audio-Visual Services, pp. 56-57, The Macmillan Co., New York, 1959.

valuable for this role would be motion pictures, television, and carefully prepared colored-slide sequences.

2. Audio-visual materials help the teacher provide meaningful sources of information. Example: Students may turn not only to printed books and leaflets for information. Audio-visual materials, that is, diagrams, charts, exhibits, photographic enlargements, motion pictures, models, demonstrations with apparatus, slides, etc., may be meaningful adjuncts of an instructional sources system. Students need to get or be given directions for procedure, facts about situations, and vivid descriptions of applications of principles. Clarity of communication and speed of comprehension may be enhanced through wise teacher use of audio-visual materials as sources.
3. Audio-visual materials may serve as springboards into a wide variety of learning experiences. Example: A teacher decides to introduce a main topic, area of work, or series of lectures by showing a motion picture to develop awareness of clusters of problems. Introduction of such work by appropriate films, slides, demonstrations, develop readiness to learn on the part of students; prepares them for tackling difficult problems and assignments.
4. Audio-visual materials provide a kit of tools for the teacher in carrying out diagnostic, research, and remedial work demanded by up-to-date instructional purposes. Example: Engineering instructors may have to turn to tape recorders, or motion picture and still-picture cameras (slow or high speed) in uncovering and correcting weaknesses in student performance demanded by practicing engineers. Automatic teaching machines, constituting another important example, may be used to detect incorrect responses in characteristic problem-solving procedures.
5. Audio-visual materials assist the teacher in overcoming physical difficulties of presenting subject matter. Example: An engineering teacher may project a complicated engineering drawing, part by part by the overlay-transparency process, thus revealing relationships in sequence as students

are ready for them. This process would eliminate time consuming chalkboard drawings semester after semester. An additional example of another sort would be the photocopying of a useful diagram for showing to the class in slide or transparency form.

There are other roles as well, and countless examples for the five roles described, but at least one of the additional roles is not applicable to Engineering instructors and hence need not be described here. When instructors develop penetrating insights into the breadth and variety of teaching objectives, when they understand better the difficulties in communication, and when they come to feel a real concern for student achievement, they will recognize more clearly the need for the help that audio-visual materials can give; help for the teacher that pays off in help for the student.

Students Deserve Good Communication Efforts

Students say they want teachers to use audio-visual materials; certainly not just because they are interesting and make time pass more quickly. Actually, most students want teachers to use audio-visual materials and to use them properly, that is to relate them with telling impact to the day-to-day class activities. Instructors who emphasize effective communication seek to give adequate explanations, seek to understand and anticipate the difficulties of students, and seek to provide the necessary real and/or vicarious experiences for building new ideas, insights and abilities.

In this short introductory chapter the need for audio-visual materials in teaching has been pointed out, and now a closer look should be taken at the various types of A-V materials and the equipment to which instructors may turn for help.

CHAPTER 2

AUDIO-VISUAL MATERIALS AND EQUIPMENT

This discussion is essentially a listing and description of the various kinds of audio-visual teaching materials. However, as was pointed out earlier, it will be less confusing if the reader is aware of the fact that projectors, tape recorders, chalkboards, and bulletin boards are means of putting content materials to work, and that such materials as models, and such processes as field trips and dramatizations need no equipment units for their application.

Later on, advice will be given on procedures for using the materials effectively, and since some of these materials are not available commercially, they will have to be made by the instructor, or by other service agencies under his direction and according to his specifications. Suggestions on such preparation will also be given in a subsequent chapter. But for the present, the possibilities should be pointed out under two headings, namely, (1) the commonly available types of materials, and (2) the newer processes now under development.

Commonly Available Audio-Visual Materials

Field Trips. Most realistic of the commonly known audio-visual materials and processes are field trips which become necessary when materials, situations, people, and construction projects have to be studies, observed, reacted to, and worked with right in their natural environments. Field trips are in themselves only processes by which the study of real things is implemented. They are difficult to inaugurate during regular school days on a formal class-group basis because of time schedules, transportation problems, and extra student costs. However because of their great realism and stimulation the method should be considered and used on extremely significant content. A few pertinent suggestions will be given in Chapter 3 concerning this oldest of audio-visual methods.

Objects, Models and Apparatus. Next to field trips in degree of reality are the real things, the models (some of them with working parts, then named mock-ups) and the demonstrations using apparatus. Such apparatus set-ups are often the counterparts of on-the-job machinery or construction components. As valuable as such materials are, they are often difficult to see and comprehend. Not everyone has a front row seat, and often too little creative problem-solving activity is demanded of the students who view these materials.

Motion Pictures. Motion pictures may provide intensely realistic experiences for Engineering students, and it is hoped that many more films will become available in the near future that have been produced for specific teaching purposes in Engineering courses. Skill-building films that give directions for action, and films that show processes, define problems and show people at work on vital engineering projects, may if properly used, play significant roles in teaching and learning. Films may be used with or without their sound tracks, and in their entirety or in segments. In fact the so-called film clip has "come into its own" as a visualization technique in television. Instructors should learn to use films as an integral part of their communication efforts, since they are the most realistic of all the graphic materials.

Still Picture Materials: Projected and Non-Projected. Many engineering instructors are today making strikingly successful use of colored 2" x 2" slides and so-called overhead projector transparencies in 7" x 7" and 10" x 10" sizes. Techniques for the latter have been well developed and widely used in Armed Forces training programs. Photographic enlargements (sometimes called flat pictures and study prints) are effective for display purposes in or out of the classroom as well as for projection by an opaque projector, and both sound and silent filmstrips are available in limited numbers for classroom purposes. Still-picture materials lend themselves most effectively where prolonged analysis of a single fixed situation is necessary. However, in terms of presently limited sources of supply, teachers need to learn to prepare their own materials or give instructions to others about what kinds are desired. Overhead transparencies as well as slides are ideal media for the projection of the many diagrams and charts that Engineering instructors need to use for best teaching results. More will be said about teacher preparation of materials in Chapter 4.

Charts, Diagrams and the Chalkboard. Charts and diagrams large enough to be seen by students in the back rows are expensive to have made, and of course they are hard to preserve for repeated use. Hence instructors turn to slides and transparencies, or they spend long hours at the chalkboard each term sketching the same drawings. The recommended procedures that are most economical of time, effort, and money are regular photographic and diazoammonia processes. If flip charts are employed then instructors should tell their artists to use large letters and numbers. The chalkboard, as a display medium for symbols, both verbal, numerical, and graphic, calls for special techniques and these will be pointed out in Chapter 3 under special considerations. Instructors are also reminded of the value of pointers to focus attention of viewers for projected, non-projected materials and for chalkboard diagrams. A few precautions to take with pointers will be emphasized a little later.

Audio-Materials and Voice Amplification. The magnetic tape recorder offers several possibilities, not the least important of which is to record interviews with practicing engineers relative to special planning and construction problems. Also, if outside-of-class listening facilities are available, the instructor may arrange for his own recorded instruction and special directions for problem analysis to be available in libraries and reference rooms with headphones. The use of microphones in large classes demands special facilities such as the yoke microphone that frees a lecturer's hands and allows him to turn to write or sketch on the chalkboard. Whereever loudspeakers are in the same room with the lecturer, lapel and necklace microphones may not be satisfactory since the high volume level that is necessary generally produces a feedback (squeal from the loudspeakers, or a ringing sound accompanying speech). In television studios for example, microphone volume may be turned up extremely high because no public address loudspeakers are present. Generally, instructors should stay close to the mike at all times, never turning away from it. Yoke mikes permit close-to-mouth positioning and hence need lower volume settings, and they are therefore recommended.

The teaching tools discussed in the preceding paragraphs are indeed commonly known today, although in many schools, the needed equipment, classroom light-control systems, and service personnel are not yet available in such quantity that teachers may use them fully without inconvenience. But even as the lack of full development in some quarters is deplored, still newer technological developments are being made and still newer tools and processes are being introduced. These are discussed in the next section.

Some Newer Processes on the Way

Television. Engineering instructors may use television in two basic ways. First, they may find that valuable program content by change is being radiated from off campus commercial stations, and that such material if observed closely by students at the request of instructors may contribute indirectly to desirable understanding of engineering processes. Second, Engineering instructors may use closed-circuit television at local campus studios to give instruction to large classes of students or scattered smaller groups. Such instruction may involve basic directions for solving problems, gathering data, analyzing difficulties, and giving pre-laboratory instruction in procedure. In another application of campus-originating programming, large groups may be reached by unusually talented teachers or distinguished guest demonstrators who could assist the regular instructors in achieving their objectives. This means that regular instructors would be in their classrooms at the time such instruction was presented, or at least they would follow-up such programming by their own efforts to direct student application. These possibilities ought not be overlooked, however, local resources and equipment will determine the degree to which the value of such procedures are realized. The trend toward such processes in teaching is quite obvious. Right now the technological climate is favorable even if financial support is weak. But still another teaching tool is on the way, namely, the so-called teaching machines.

Teaching Machines. The term teaching machines should not be confused with the projectors and tape recording devices previously discussed. In defining the basic difference A. A. Lumsdaine pointed out that, "All of the devices that have been called teaching machines . . . present the individual student with programs of questions and answers, problems to be solved, or exercises to be performed. In addition, however, they always provide some type of feedback or correction to the student, so that he is immediately informed of his progress at each step, and is given a basis for correcting his errors."

Such machines may of course be used to administer and score tests, but more important still, teachers will conceivably work out learning sequences in great detail, or purchase them readymade, and after proper introductory work, problem definition, and visualized presentations turn students over on schedule to a battery of automatic machines that will serve as relentless, unerring tutors following through on individual student progress, correcting each response as he follows a step-by-step procedure. Machines like these have long been used in research projects, and today, some models no bigger than a typewriter and others fully electronic, costing $5,000, are on the market and presently in practical use. Years ago Sidney L. Pressey and his students at Ohio University, devised punch-board question and answer devices using multiple-choice arrangements. Students punched an answer to a question and if the selection was correct the pencil point would sink through the paper covered holes far enough to mark a scoring sheet underneath. If wrong, the pencil point would be stopped thus indicating that the student should engage in further deliberation. Obviously, so-called teaching machines will demand of instructors or their service agents the highly developed ability to program instructional tasks in such a way that students may work by themselves at individual rates. This introduces the concept of automation and self-instruction processes.

Automation and Self-Instruction. Nobody is suggesting by such words that an engineer will be trained by a battery of machines. They do imply that by means of "tutoring" machines and creatively programmed learning exercises which demand reading, study, verbal and numerical responses based on slide-rule computations as well as subjective judgments, students will be required to do a considerably greater amount of independent work, or as it is called, self-teaching. The crucial aspect of such processes is the creative organizational and learning analysis work to be done by the teacher. There can be little doubt that as classes come together for certain phases of group instruction the commonly known instructional materials will be more important than ever. Getting students ready for laboratory and automatic machine activity will be along with the programming of learning a basic teaching task.

Self-instruction is not a new concept and good teachers have probably always made such processes possible. Teachers today prepare special work and guide sheets to promote self-instructional activity. And certainly learning by students is an intensely personal matter even though it has been believed that it is most efficient in a group situation. So back to the regular classroom, day-to-day procedure for a discussion of how to use audio-visual materials effectively.

CHAPTER 3

USING AUDIO-VISUAL MATERIALS EFFECTIVELY

Audio-visual materials, despite their interest-compelling power, are not magical. Instructors need to perceive these tools as the means of accomplishing recognized ends. Effective use simply means putting materials to work efficiently to achieve valid teaching objectives. Thus teacher competence in this field arises out of a complex of beliefs, commitments to action, and the ability to make up a set of unique decisions about what to select and what to do or say, when what has been selected is presented in class.

This chapter explains and suggests a system of principles, not a recipe, but a linked series of guideposts that call for creative teacher action. Five principles will be stated and related to teacher performance, and some special considerations for selected materials and processes will be dealt with.

How to Select A-V Materials

The Principle of Selection. The first critical task in using audio-visual teaching materials effectively is to find and choose the ones that meet student needs and interests, that are suitable for students' maturity and experience levels, that deal appropriately with subject-matter areas under study, and the ones that will help students solve their problems. The guiding principle for this action is as follows: Teachers should base their selection of high quality audio-visual materials upon valid teaching purposes (objectives) and upon the unique characteristics of a specific group of learners. Very simply, the crucial aspects of the principle are production quality of the material, the purpose to be achieved by it, and student characteristics.

Teaching Purposes. Many teachers choose films, slides, and models, because they seem to coincide with subject-matter content in a given text book. The best way is to choose a particular teaching aid, be it television program or filmstrip, model or field trip, because it will help students get specific insights, develop ability to perform a specified engineering task, and develop proper attitudes like criticalness for example, and appreciations of such actions as good planning and clear thinking. Having such specific purposes in mind will help instructors predict the value of any given kind of material or proposed learning experience. Linked with this important basis for judgment is the need for knowledge about a students' maturity and experience background and the technical excellence of an audio-visual production. Teachers need to judge whether content is too easy or too difficult for a specific group, whether it is accurate and typical, and in case of existing defects if the materials will impede learning or waste time.

Pre-Use Examination. It is obvious that valid teacher judgments cannot be made about materials without examination by viewing or hearing them. Catalog descriptions and reported judgments of other teachers and colleagues may help. However, some materials may contain embarrassing and disruptive content, and this situation is more likely to be encountered in motion pictures produced by other than bona fide school-material agencies. Furthermore only when another teacher's purpose for using a given material is known should his recommendations be accepted.

Sources of Materials. Locating suitable A-V materials is not an easy task for the teacher. Since there is no clearing house agency, the search must be made continuously by teachers everywhere. In general, the available motion pictures on any topic, are the easiest to find since there is a published national source book that is kept up to date by quarterly supplements. There is also a source book for filmstrips by the same publisher, and engineering and construction journals, especially the Journal of the American Society for Engineering Education, will doubtlessly carry advertisements relative to new audio-visual materials and developments in instructional technology. Engineering teachers should also be continually on the lookout for good teaching materials that are produced by industrial agencies.

Such films and filmstrips are generally distributed on a free-loan basis, and they are for the most part listed in the source books just mentioned or in specialized free-material lists. In addition to such publications, every Engineering instructor ought to familiarize himself with the motion pictures, filmstrips, models and charts listed in the source book Educational Aids for Engineering, published in March 1955, as the result of an extensive study conducted by a special committee under the direction of the ASEE.

The following is a listing of general references and suggestions that may prove to be helpful:

(1) Make a thorough study of the ASEE source book, EDUCATIONAL AIDS FOR ENGINEERING, available from the American Society for Engineering Education, University of Illinois, Urbana, Illinois, price $1.

(2) Consult the EDUCATIONAL FILM GUIDE for 1953, and for 1954-1958 plus Supplements, and also the FILMSTRIP GUIDE published by the H. W. Wilson Co., 950 University Ave., N. Y., N. Y. Public libraries, public school and university audio-visual service centers usually have these on file. Engineering libraries certainly ought to have them too. Materials in these source books are classified under broad as well as specific engineering topics such as Engineering, Hydraulics, Bridges, Construction, etc. The price of the motion picture source book including supplement service is approximately $20.

(3) Consult EDUCATORS GUIDE TO FREE FILMS ($7), and EDUCATORS GUIDE TO FREE SLIDEFILMS($6) published annually by Educators Progress Service, Dept. AVG, Randolph, Wisconsin. Audio-visual centers may have these publications also.

(4) Consult the American Society for Engineering Education Journal being on the lookout for announcements, and seek to exchange information about valuable A-V materials with instructors in other schools.

(5) Write to such transparency-material manufacturers as Tecnifax Corp., Holyoke, Mass. This company is embarking on a production-of-transparencies program. It is likely that some engineering content is already in their plans.

(6) Consult film catalogs of the largest rental film libraries, for example University of Illinois, Urbana; Indiana University, Bloomington; State University of Iowa, Iowa City; and others.

(7) Consult catalogs of scientific equipment-producing companies and manufacturing promotional agencies, such as the Petroleum Institute and the Manufacturing Chemists' Association.

How to Develop Readiness

The Principle of Readiness. The second fundamental principle is that the use of audio-visual instructional materials should be preceded by the development of adequate learner readiness for effective participation. When teachers know why they are using films, slides, charts, models, etc., the job of developing readiness in students is easier to carry out. For example if a teacher wanted to develop the ability to interpret a specific type of engineering drawing, then it would be an easy matter to suggest the highly pertinent aspects of a given film that students should be sure to observe.

Some Readiness Techniques. Students need to feel that an activity is important to them, and often this can be accomplished by telling them how a particular material will contribute to important learning results. Perhaps the best way to develop readiness is to set up one or more problems or tasks and then explain that the film or filmstrip, or set of slides, will help define, analyze and provide directions for the necessary solution. Instructors who use the illustrated lecture method may greatly enhance communication through questions and problems that are raised as a preface to using charts, slides, etc. Problem-solving (question-answering and formulating new responses) activity needs to be a dominating characteristic of the teaching-learning process, and thus it follows that the use of audio-visual materials ought to either lead to the raising of problems, or the identification of problems should precede them. The following are suggested as examples of what to do or say prior to the use of A-V materials:

(1) Give an introductory talk, describe a case, or tell about an incident that introduces the content to be presented.

(2) Set up a problem or assignment to focus attention on a felt need for learning, or raise a series of questions, perhaps putting them on the chalkboard or handing them out in duplicated-sheet form. (Here it is obvious that having teaching purposes in mind is essential since without them proper questions and assignments will be appropriate and pertinent only by chance.)

(3) Tell how the content to be presented by film, model or demonstration is related to previous experience and future plans and assignments or on-the-job performance.

(4) Direct attention of students to key processes, issues, or ideas in line with teaching objectives. Perhaps three to five references of this nature would be sufficient. Prior to lengthy motion pictures or other programs of activity, these references should be written down by the student.

(5) Point out some difficulties that will be encountered.

(6) When using unusually realistic materials state that the material provides opportunity to "travel" to the location for on-the-spot observation.

One or more of these and other choices of action will be sure to stimulate students to greater mental and physical participation as the case may be. Following the readiness principle means that plans of action to start students off on fruitful thought processes will be in mind and will be implemented.

How to Make Suitable Physical Arrangements

The Control of Facilities Principle. The next logical step in utilization of audio-visual teaching materials has to do with the control of conditions that facilitate learner attention and action. The basic principle may be stated as follows: details relating to physical facilities and conditions for using audio-visual materials should be handled or arranged by the teacher in a manner that safeguards material and equipment and provides for economy of time and optimum learner attention.

Basic Classroom Conditions. The teacher must become an excellent organizer if the previously stated principle is to be followed. If he doesn't have to operate his own equipment (motion picture projectors, etc.) he still needs to plan out the action and in general assume command. Bearing in mind all of the kinds of A-V materials there are six basic classroom conditions that should be met. They are as follows:

Condition 1: Sufficient darkness to permit the viewing of bright, impressive projected pictures. One tenth foot-candle is the desirable lower limit of illumination.

Condition 2: Appropriate placement of projectors and screen together with the kind of seating arrangement that will prevent eyestrain and eliminate picture distortion and dimness. No one should sit closer than two times the width of the projected picture, and no one should be seated farther away than six times the picture width. Also, instructors should see to it that students are seated close to the projection axis and all within a total angle of forty-five degrees if a glass-beaded screen is being used, and within sixty degrees for matte white screens.

Condition 3: Proper placement of sound speakers for effortless listening. (Should be placed at front of room on a table or chair, and beamed at listeners).

Condition 4: Correct adjustment of tone and volume controls on sound equipment for maximum intelligibility. High-frequency tone emphasis improves intelligibility.

Condition 5: Suitable placement of models, charts, diagrams, posters and maps for convenient observation and activity.

Condition 6: Satisfactory timing of planned-for presentations to avoid interruptions and postponements.

Operational Skills. Control over mechanical devices can be exercised only when teachers have developed, through practice, the necessary operational skills. Although each of the devices has its own unique characteristics, all picture projectors possess similar elements such as lenses to be focused and lamps to be changed. Other kinds of devices such as record players, tape recorders and television receivers also have common elements of construction. Such similarities make the task of developing competence in operation less difficult.

It should be pointed out that actually in an increasing number of cases competencies in the personal operation of physical facilities are unnecessary. Many classrooms are today equipped with adequate darkening devices, projectors are delivered, and equipment operators are provided through central agencies. In cases like these the teacher's responsibility for competence lies in his control over several of the previously stated basic conditions. There are of course varying degrees of audio-visual service available to teachers, from the situation where a teacher must go to the service center to pick up the projector, screen and material and install portable darkening shades personally, to the situation where, at the scheduled time, his selected materials are delivered, and devices set up and operated when the signal to begin is given. Engineering staff members should urge university administrators to take action to provide desirable instructional services wherever they are lacking.

Summary of Teacher Performance. Since Engineering instructors possess a technical and scientific background the operation of equipment and control of the basic conditions mentioned would be easy indeed to learn, however, the following summary of action to be taken may serve to point up the pitfalls that should be avoided:

1. Personally operate, or make arrangements for, the use of those devices which can make significant contributions to learning.

2. Judge excellence of out-put of all devices selected for use and make or direct corrective adjustments where necessary: change lamps, obtain best focus, clean dirty lenses and mirrors, clean aperture, and obtain appropriate tone and volume levels.

3. Save time by enlisting cooperation of students when such cooperation is not detrimental to learning.

4. Judge adequacy of darkening systems for various types of picture projection.

5. Devise seating arrangements for optimum seeing and listening, or provide for freedom of movement, according to the material and for equipment being used. (The viewing of demonstrations and charts may call for special arrangements.)

6. Plan the timing of the planned-for presentation to prevent dissatisfaction because of interruption or postponement.

How to Elicit Desired Responses to Materials

The Action Principle. No teacher performance with audio-visual materials demands more professional know-how than do decisions relative to teacher action during and immediately after the use of audio-visual materials. Stated simply, the guiding principle is this: Teachers should guide the learner in the important processes of reacting to and taking appropriate action as a result of audio-visual experience situations.

Teacher Objectives as Determiners of Student Response. In previous discussions of the selection and readiness principles it was pointed out that having clear-cut teaching purposes (the abilities and insights, etc) in mind was of vital importance. When eliciting desired responses of students to classroom materials there is no other system for teacher guidance than the valid teaching purposes identified ahead of time by the instructor. Deciding what to do or say is the creative function that every teacher must face, and it ought to be recognized that if the film or other material was chosen to contribute to the development of a specific ability, then a practice session should follow the showing, either in or out of the classroom, either under direct teacher supervision or on a self-instruction basis. On the other hand if concepts and understanding important principles are to be the learning products, then activities involving provocative questioning, discussing, lecturing, investigating, studying, and applying in correct balance are called for. Teachers delude themselves when they elect to give the "regular lecture" and then just show a film, or some other material, in addition. Audio-visual materials "pay off" when students learn how to do something important. Before teachers can determine what and how much student action is necessary, they must know why.

Problems and Assignments. When teachers set up problems and assignments (for completion either in or out of class) and relate their use of audio-visual materials to them directly, planning what to do or say will be easier than under any other condition. That is, there is never any doubt about what to do next, since the solution to the problem or question (not necessarily computational) needs to be checked, clarified or advanced to the next stage of action. Some A-V materials like filmstrips, slides, charts, and the use of apparatus for a demonstration, permit step-by-step, picture by picture participation. Others, like a twenty-minute film, call for student-controlled reaction and observation, with personally led teacher-action being delayed until the completion of a program. Student reactions should not be left to chance, however, and for guidance purposes teachers ought to recognize the importance of the thought-type question. Questions during or after audio-visual presentations may be simple, calling for spontaneous reactions requiring a minimum of mental effort; or they may demand recall of content, comparison of conditions, with consequent selection and judgment. Still a more complex type of question or problem would involve planning, investigation of the facts through extended study followed by generalization. The first two can probably be resolved by on-the-spot discussion, but the last type of problem or question growing out of A-V experiences seems to call for project work, construction, writing and field-work all involving vital practical effort.

Lecturing. Instructors who employ lecture methods predominantly need to consider the kind of explanation that should be given during and/or following A-V presentations. Shortcomings in the content need to be pointed out, and kinds of subsequent action that should be taken by students need to be described. Lecturers should above all realize, as has already been pointed out that A-V materials should not play the role of an appendage. That is, the lecture content should incorporate A-V material into a new unified whole with a new vital communicative impact on the student, and indeed, when this impact occurs, it will be because student mental responses and resolves have taken place.

The important processes just described have been related to the use of A-V materials. They are basic teaching processes, and they are basic to the use of all teaching materials, printed, audio, visual, and automatic machines. Guidance of learning acticity is what teaching is, and what is being said is that teachers everywhere must give more attention to the determination of their objectives because these determine what teachers need to do and say, what pupils need to do, and what materials need to be procured and put to work in the process.

How to Appraise A-V Methods

The Appraisal Principle. There is still another aspect of teacher performance that must be brought into sharp focus, namely, that of critical appraisal. The basic principle for this performance is as follows: Teachers should subject both the audio-visual material and the accompanying techniques to continual evaluation.

Basis of Value. Audio-visual instructional materials have no "magic" in themselves. Their values are rich potentials to be released by teachers through the manipulation of teaching-learning situations. Their values can be recognized only in the results of their use. Projecting a picture on a screen, or placing a model of a hydraulic mechanism on a table in front of a group of students, provide no assurance that learners will draw the best conclusions, or change their behavior in desirable ways. It is the crucial linkage of audio-visual materials between teaching purpose and pupil accomplishment which determines their value. Implicit in the discussion of each of the previously discussed aspects of the utilization process was the factor of teacher judgment. Did the judgments relative to the selection of a particular kind of material, to the means designed to develop interest and needs; and to the techniques devised to elicit reaction and participation, bring about the realization of planned-for achievement? To be competent in this area of evaluation each teacher must seek and find the answer to this question. Without this process of self-criticism the teacher cannot discover wherein strengths or weaknesses in methods lie, and improvement then becomes impossible except by chance.

Appraisal of Materials. If a particular kind of audio-visual material has been properly selected before inclusion in teaching plans, it has already been subjected to a careful appraisal in terms of high quality, of purposes, and of characteristics of a specific group. Evaluation after, or during use, however, demands a satisfactory check-up on the original judgments. Such questions as the following need to be kept in mind and answered by the teacher:

(a) What did students like about the content of the material I used?

(b) Did students react to the content the way I hoped they would?

(c) Was the material as appropriate as I decided it would be for my group?
(d) Was the material actually worth the time and effort, or should I locate another type of material?
(e) Did the content of the material help me to release the energies of my pupils?

There is no rule of thumb by which a teacher can develop an unerring procedure for selecting just the right materials for use at precisely the right time. Continual scrutiny of the materials used in terms of observed student responses in specific situations offers the most rewarding means of improving judgment.

Appraisal of Techniques. The second of the two points of departure for the teacher's evaluation is his appraisal of his own plan of procedure. The basic task in carrying out the appraisal of techniques utilized is the determination of the degree to which these procedures achieved the desired results. Prior to actual use, the plan for building readiness and the plan for reaction and participation are, or should be, the best possible in-advance judgments as to what will work. The results of the plan need to be scrutinized. In cases where procedures do not produce the desired results in learners, the teacher must find out why. Such guide questions as these will be helpful:

(a) Was the material too trivial or superficial for the characteristics of the group?
(b) Did I misjudge the readiness of the group?
(c) Were my thought-type questions poorly phrased for the kind of mental action I needed to obtain?
(d) Did the activities resulting from my use of the material lack challenge and significance?
(e) Are my purposes valid?
(f) Were circumstances beyond my control at fault?
(g) Are the sources of my evidence for appraisal valid?

Teachers may find that calling upon students directly to assist in evaluating materials and methods is also a fruitful way of identifying strengths and weaknesses.

In the preceding paragraphs five basic principles have been discussed as a system for guiding teacher decisions relative to the selection and use of audio-visual materials. In Chapter 2, various kinds of audio-visual materials were listed and briefly described, and a number of these have been referred to in the discussions of guidance from principles. It should be emphasized that the system of principles just discussed works for all audio-visual materials, however, instructors need to familiarize themselves with some of the unique characteristics of media they wish to put to work. Therefore some specialized suggestions are given in the following section for using certain kinds of materials and techniques that may not have received necessary mention elsewhere.

Some Special Considerations for Materials and Processes

Field Trips. Instructors are busy people. Their hands are full enough with formal educational planning and activities without assuming additional burdens of the highly informal activity that is characterized by most field trips. Hence a few special suggestions follow:

(1) Organize and conduct field trips only when they provide rich experiences that lead to building specific skills.

(2) Set up a vital problem, either constructional or investigative in nature, and then plan the trip as the means of solving the problem. That is, analyze the problem and guide students in getting the facts needed by actual on-the-spot observation.

(3) Teachers are advised to seek public transportation, or if private cars have to be used, adequate insurance ought to be procured for the trip's duration.

(4) Instructors are advised to find out about local precedents for this kind of learning activity, and to find out who is responsible in case of accidents to minors.

Models, Objects, and Apparatus. Instructors need to figure out as precisely as possible how much direct experience with real things is needed before abstractions presented in rapid-fire fashion are made meaningful. Furthermore the level of experience possessed by students needs to be assessed in order to communicate effectively. Models and apparatus may be far more effective in promoting understanding than words alone, but certain dangers need to be overcome. Hence the following suggestions should be considered:

(1) Instructors should make sure that misconceptions due to inconsistent scale, color and shape are corrected.

(2) Instructors should make sure that materials may be clearly viewed, read, or interpreted. Large labels should be used when necessary.

(3) Instructors should ask questions about predicted happenings or changes that are to take place to emphasize powers of student observation, inference and response.

(4) Models and apparatus may also be arranged with labels and questions for student observation outside of class time. Additional assignments may be made that call for reports based on observation.

(5) When demonstrating with apparatus, instructors are advised to recall that students are facing the instructor and that right-left hand positions are accordingly reversed. Hence, changes in orientation for right-left actions should be called for if students are supposed to be following motions in their own minds.

(6) The difference between models and apparatus and the real thing need to be brought out by questions and explanations. Also when real objects are shown and observed, student concepts relative to the real-life setting for the objects need to be checked for accuracy.

(7) When planning to conduct demonstrations using models, objects and apparatus, instructors ought to list items needed and write out the step-by-step procedure anticipating difficulties in understanding likely to be encountered by students. The experiment or demonstration should be actually rehearsed whenever feasible prior to performance in front of the group.

(8) Chalkboards may prove to be useful in connection with demonstrations for outlining main points for students. Slides and charts may also be helpful to explain complicated processes.

(9) Whenever time permits students ought to be stimulated to ask questions and draw conclusions.

Chalkboard Techniques. Engineering instructors are constant users of chalkboards. Of course those instructors who have overhead projectors in their classrooms will not want to spend hours redrawing complicated diagrams every semester, but the chalkboard is likely to be used so much that some suggestions are in order:

(1) Write or make figures on the board and then walk back to the rear of the room to ascertain viewing difficulties of students in any given room. Size of letters and numbers should be increased as deemed necessary. Check readability due to glare of sunlight or room light.

(2) Use templates for standard figures commonly needed for board work.

(3) Use the hidden board technique by covering sections of the board with wrapping paper strips.

(4) Do not block view of chalkboard content. Stand to one side. Use pointer to focus attention.

(5) Diagrams or drawings may be put on ahead of time with barely visible lines, and then filled in boldly in front of the class during the presentation. Some instructors waste too much valuable class time by making complicated drawings while class members idly watch.

Use of Pointers. When presenting content by charts, diagrams, maps, or by chalkboard drawings, a pointer will allow the instructor to focus attention for purposes of explanation. Teachers should heed a few hints. Use the pointer only when it is valuable, then lay it down. Don't hold it, tap with it, point at people with it, bend it, or touch the floor with it.

Charts and Diagrams. One pronounced problem that must be borne in mind continually has to do with the visibility of details and lettering. Instructors must either point to and read the difficult to see lettering or arrange to have students view the chart in small groups. Another serious problem is the need to bridge the gap between the diagram and the reality it is supposed to represent. Teachers need to question students about their experience levels and understanding, and ascertain whether misconceptions of the real thing or process exist, making corrections as needed. Whenever charts and diagrams have to be prepared, instructors should bear in mind that small illustrations in texts may be enlarged by projecting them by means of an opaque projector in darkened rooms on white wrapping or poster board paper, taped in sections to chalkboards. Instructors should consider remaking their diagram and chart material into slide or transparency form for more effective use and easier storage and handling. The preparation of such materials is dealt with briefly in the next chapter.

Filmstrips. When filmstrips are accompanied by tape or disk recorded commentary, the presentation will probably be carried out from beginning to end without interruption. However, many instructors prefer to select certain pictures from a filmstrip, skipping all intervening, insignificant content. During the skipping process light may be dimmed by putting part of the hand over the lens barrel while the chosen picture is being turned into position. Instructors need to conduct participatory activity for each frame, questioning and explaining as the content demands.

Audio-Visual Techniques in Combination. Special physical problems are encountered when instructors plan to use several kinds of material during any given class period. Projectors easily get in the way and block the view of students. To solve this problem instructors need to keep slide, filmstrip and motion picture projectors at the rear of the room on mobile projection stands. Usually however, this is impossible where 2-inch by 2-inch slides are to be used because the normal slide projector lens will more than fill the screen. Hency teachers should get help from audio-visual consultants or dealers in recommending lenses of correct focal length for the specific projectors to be used. Overhead projectors have to be near the front of the room anyway, and here the only problem is to prevent blocking students' vision. A low projection stand 18 inches to 24 inches in height is often the answer. Making an aisle in the center of the room is another possibility, as then the projectors may be arranged down the aisle at appropriate distances from the screen. Teachers need to plan out such multiple activities in their rooms and call for the help of extra projectionists if needed. In this instance there is nothing quite like the television camera with the electronic remote controls for projecting film clips, slides, models, charts and photographic enlargements, each on cue from the director. Such efficiency is next to impossible to achieve in the classroom short of a corps of projectionists, or a fast-stepping teacher in a wide aisle, or a modern push-button classroom that is just beginning to appear in schools where the purse strings have not been as tightly drawn as in most.

CHAPTER 4

PREPARING SIMPLE MATERIALS

Engineering instructors may find that the only way to procure the teaching materials urgently needed to achieve their objectives is to make them. In some instances where service centers are available they need only to consult with local producers and state the specifications for films, slides, charts, or transparencies. Fortunate indeed is the instructor who has such services at his disposal. The less fortunate, who nevertheless have the necessary equipment on hand, may, through their own ingenuity and drive, procure needed supplies, and following reasonably simple directions become successful producers. The following pages suggest possibilities for action.

Motion Picture Segments

Motion pictures of a specialized nature are in general expensive to produce. The sound-track alone for a 400-foot reel may run two to three hundred dollars as a minimum. However, an enterprising instructor with a 16mm camera may shoot a hundred-foot film segment of an important process or an installation for less than eight dollars. And if a magnetic motion picture projector is available, a sound track may be added that will preserve and standardize significant instructional commentary. Instructors should remember that a 20-minute motion picture subject, as desirable as it sometimes is, may not serve as effectively as a how-to-do-it film segment. The cause of a caved-in bridge span, or the method for using a strain gauge may be effectively analyzed by means of an easy-to-make 100-foot film sequence made by an on-the-spot instructor. Television programming has certainly revealed the value of short film sequences to show a bit of pertinent action, and the same need exists in modern classrooms.

Instructors who set out to make their own film sequences need to jot down in advance just what needs to be shown to clarify any given problem, and they ought to be liberal with close-up shots for providing significant details. When others do the shooting upon request, conferences need to be held for the sake of a clear understanding of needs, or detailed written descriptions ought to be prepared and supplied to the photographer for getting the footage desired.

Opaque Projector Material and Mounted Pictures for Display

Teachers who are continuously searching for significant visual materials often find diagrams, charts, and photographic illustrations in magazines that may be cut out and taped to mounting stock for use in an opaque projector. Opaque projectors do not as a rule project images that are as sharp as desired, and when rooms are not adequately darkenable this method is quite unsatisfactory. Moreover, find print accompanying graphic illustrations is almost never readable in the projected image by viewers seated back of the first three rows.

Opaque projectors especially of the older variety (7-inch by 7-inch projection area) are especially valuable in enlarging diagrams and small charts. In these cases chart paper or wrapping paper sections are secured to the chalkboard or wall spaces and the projected image is traced.

Pictorial and graphic materials of value in any given course may be mounted on suitable mounting surfaces by dry-press methods, involving dry-mount tissue and Chartex fabric, or by rubber cement. Such materials, mounted or not, may be displayed by tacking them to bulletin boards, taping them to wall surfaces, or suspending them by small clips from wire.

As has been pointed out earlier, the way such pictures fit into lecture, demonstration, observation and assignment procedures determines worthwhileness of the effort involved. At any rate, the first job of the instructor is to locate valuable graphic materials and then find help for preparing them for projection or display.

Non-Photographic Slides: 3½-inch by 4-inch Size

Because almost every college and university has several unused lantern-slide projectors around that could probably be procured on long-term loan, instructors ought to explore the possibility of tracing important textbook diagrams and charts on etched glass with soft lead pencil. Special slide crayons may be used to add color for emphasis. The following basic materials may be purchased from the Keystone View Co., Meadville, Pa.: Etched glass 3½-inch by

4-inch, lantern-slide masks with 3-inch by 2.75-inch aperature, clean cover glass, and half-inch slide-binding tape. Transparent lantern-slide inks are also available for this purpose.

Simple rules and hints are:

(1) Draw on the etched surface only.

(2) Always outline the drawing in pencil for good definition.

(3) Apply crayon or ink evenly up to the pencilled lines.

(4) If masks are not being used, do not draw figures closer to edges of glass than 3/8 inch. The size of drawing that can be used by this method is thus limited.

(5) Spraying the glass with Krylon may make the slide more transparent.

(6) If smudges are made, start over again.

(7) If slides are to be saved, cover with a clear cover glass (buy at any photo store) and bind glasses firmly together. Remove finger prints with a damp cloth.

A $3\frac{1}{2}$-inch by 4-inch lantern-slide projector at the rear of the room on its own projection stand, available for intermittent use during any given class period would be a tremendous time-saver and would be as indispensable for the Engineering as for the Art Appreciation instructor.

Three-Minute Polaroid Slides: $3\frac{1}{2}$-inch by 4-inch Size

The Polaroid 46L film develops a positive image on clear film instead of on paper. This film may then be mounted in a special, commonly available cardboard mounting frame for immediate projection. This process is of instructional value because it makes possible three-minute copying of diagrams and other graphic illustrations from a wide variety of sources.

The Polaroid Copier outfit costing approximately $250 is necessary for doing this valuable work. Such outfits are generally available in A-V Service Centers, but if they are not, the Engineering library workroom might be a good location for equipment of this sort.

The Polaroid slide surface is sometimes subjected to a certain amount of buckling, and for effective preservation, Polaroid slide transparencies ($3\frac{1}{2}$-inch by 4-inch) may be placed with a lantern-slide mask between two clear cover glasses and bound together with slide-binding tape. While such slides are thicker than most slides, they will nevertheless fit the usual 3½-inch by 4-inch slide carriers.

As will be pointed out later, the Polaroid slide process has other applications in the production of 7-inch by 7-inch and 10-inch by 10-inch transparencies.

The 2-inch by 2-inch Slide

Engineering instructors who are contemplating the purchase of a 2-inch by 2-inch camera for hobby use would be well advised to select a single-lens reflex model. There are many on the market at various prices. The availability of close-up kits having lenses and field-guide legs that determine the area being photographed at given pre-set camera distances, ought to be taken into consideration when deciding what brand to purchase. While any 2-inch by 2-inch camera may be used for copying, the single-lens reflex model permits the photographer to view the exact area that is being included in the picture. In other words the usual difficulty with parallax problems is avoided, and for extreme close-up work when copying diagrams, color illustrations, small charts, etc., this is an essential advantage.

The Engineering instructor does not have to be an expert photographer to produce regular color slides for classroom purposes. He simply has to have his camera handy on consulting jobs, or on vacation trips. Furthermore many industrial organizations and manufacturers may make available upon request, or undertake photographic projects on their own for special purposes, color slides that have unique value in developing student insight and skill.

Many instructors are totally unaware of the ease with which complicated diagrams may be reproduced for research reports, lectures and class explanations by means of the single-lens reflex camera. Even copying stands and lights are unnecessary if the books and papers to be copied are taken outside and photographed under sunlight conditions.

Kodachrome film is ideal for even black and white sources giving sharp definition often superior to comparable work with regular black and white film. The basic needs are one or two special slip-on, or screw-on lenses for close-up work. Larger charts and graphs in color photograph well at distances down to 3 feet with standard lenses.

When indoor work has to be done, lights on simple stands may be used to illuminate charts taped or tacked to vertical surfaces. A tripod is then needed for longer exposures than one-fiftieth of a second. Regular copier-stand equipment for indoor use makes possible speedy work of excellent quality. However, here again A-V service centers may have such equipment and suitable work areas for instructors to use by appointment, or such service centers may provide slide-making services on a low-cost or free-of-charge basis.

When preparing slides for teaching purposes, instructors should consider the need for slides in sequence, interspersing diagrams with pictorial illustrations. In effect a "shooting" plan for the sequence of slides is the counterpart of a motion picture script. Such planning will do much to facilitate desired learning results.

Overhead-Projector Transparencies

Recent technological developments in connection with overhead projectors and diazo-ammonia transparency processes have opened up a new field of graphic materials for instructors. Going hand in hand with such developments have been the photo-copier devices, some of which produce direct, clear positives, thus facilitating projection techniques.

One of the most striking projection processes made possible by these diazo-coated film techniques is the overlay or multiple-layer method of projection. By this process it is possible to project a basic image, for example a simple diagram, and then, as needed, successive layers of transparency are flipped into place building up or adding to the image development. The complicated engineering diagrams dealt with repeatedly in every Engineering classroom are uniquely suited to such overlay-projection techniques, and instructors everywhere should cooperate in producing or getting together on the preparation of specific diagrammed content to be mass-produced by organizations in the diazo-film business. Course by course Engineering instructors should pool their resources to speed up development of these important techniques. To that end every Engineering school classroom ought to be equipped with an overhead projector. There are several kinds of transparencies for use with the overhead projector and these are now briefly described to show the range of possibility for Engineering applications:

(1) Grease-pencil drawings on clear acetate sheets with Flo-Master-Pen inks for color, mounted on cardboard mounting frames. Projectors are in two sizes 7-inch by 7-inch and 10-inch by 10-inch. The latter is rapidly becoming the standard size despite increased bulkiness for transporting. Several layers of such drawings may be projected as desired in sequence.

(2) Stylus drawings with other printed or typewritten content on a carbon-coated film base, also mounted on cardboard projection frames and covered with protecting clear acetate sheets. Such diagrams may be colored by transparent inks and by colored sheets of thin acetate film.

(3) Soft lead pencil and colored slide-crayon drawings of diagrams and charts on etched acetate sheets, mounted as previously described. Such acetate sheets may be sprayed with Krylon as a means of transparentizing for increasing projection quality.

(4) Clear positive transparencies made by photo-copy processes using Contoura-Constat or similar copier equipment, mounted as previously described for projection.

(5) Transparencies made by shining ultra-violet light through opaque drawings and other graphic illustrations arranged on "master" sheets, to expose diazo-coated film. Subsequent ammonia-frame development brings out black and white or solid color images on white or tinted transparent backgrounds. Transparencies are then mounted for projection.

(6) Transparencies in multiple-layers of diazo-type film. Complex graphic material may be easily constructed with all overlays in perfect register.

(7) Transparencies may be made also from tracing paper masters on which drawings and printed content have been hand done with opaque inks.

(8) Transparencies may be made by "lifting" clay-coated color prints from magazine illustrations, subsequently mounted on cardboard projection frames.

Many exciting possibilities for teaching materials are opened up to the Engineering instructor by this aspect of technology. However, the fact that there is a paucity of readymade audio-visual materials for Engineering education purposes places a somewhat heavy burden upon the instructor to prepare his own along lines described in the preceding pages. Obviously he needs to get help. Where should he turn?

Where to Get Help

Basically the Engineering instructor must turn to other people and service centers, or he must procure materials and handbooks and proceed with his colleagues along self-instruction lines.

A-V Service Centers. Many of the larger colleges and universities today have organized A-V service centers where trained personnel are available to give assistance. A number of such centers have photographic production divisions that are equipped to turn out charts, diagrams, slides, mounted pictures, motion pictures, and models. Engineering instructors should consult such local staff members and ascertain the nature and limitations of the services presently available. They should then take care that their requests for materials have been carefully thought through in terms of teaching effectiveness and in terms of classroom viewing and utilization conditions, that is, in the light of available projectors, room darkening facilities, display areas, and capacity of students to interpret details of the materials displayed or projected. A word of caution is in order. Instructors should not insist on crowding too much material on one slide because when the printing in instructions, explanations and labels is too small, it simply cannot be read by remote viewers.

Guidance for Self-Instruction. Where self-instruction processes are necessary, a group of instructors should procure a few basic references and a number of the available pertinent motion pictures for study as a follow-up to the general treatment in this present paper. Then considering developing interests and capabilities and needs, the group should organize clinics to be supervised by campus hobbyists skilled in specific production processes. Equipment units for photo-copy and the processes may then be purchased, and a a plan set up for ordering and replenishing the needed expendable supplies. Help may be possible from still another source. There is available on every campus talented students who themselves have developed desirable skill in hobby pursuits during earlier school days and this suggests the possibility of organizing a paid student-production crew. Such a crew would of course need an assigned laboratory space for carrying out the work. At any rate the important motion pictures and basic references that would help Engineering instructors in self-study programs are listed in the next paragraphs.

A Few Basic Motion Pictures. This list is not intended to be inclusive, but each of the items is highly recommended:

(1) Accent on Learning, showing the college-level use of a wide range of audio-visual materials. Available from Ohio State University, Photographic Laboratory, Columbus 10, Ohio.

(2) Handmade Materials for Projection: How to Make Handmade Lantern Slides; Lettering Instructional Materials; and Photographic Slides for Instruction; all available for purchase or rental from Indiana University, Audio-Visual Center, Bloomington, Indiana.

Some Basic References. It is always a temptation in cases like this to list so many books and booklets, out of deference to colleagues in any field, that the reader's action is impeded. The following list in this case is not of this nature. The recommendation is highly selective and to the point. Engineering librarians should under guidance and pressure from instructors set up a small professional library of books and booklets about A-V methods. The following constitute the minimum:

(1) An absolute must in the light of this last chapter is a profusely illustrated, how-to-do-it booklet that every Engineering instructor ought to possess if he desires to learn how to prepare materials on his own. The title is, A GUIDE FOR USE WITH THE INDIANA UNIVERSITY FILM SERIES IN THE AREA OF PREPARATION AND USE OF AUDIO-VISUAL MATERIALS. The price is $2, the address is Indiana University, Audio-Visual Center, Bloomington.

(2) At least one basic textbook in the field of A-V methods. Excellent texts by Wittich and Schuller with Harper and Brothers, by Kinder with American Book Co., by Dale with

Henry Holt Co., and by Brown, Lewis and Harcleroad with McGraw-Hill, and many others, are available. The writer believes that the inclusion of illustrated equipment-operation content as an appendix may make the last named volume somewhat more valuable for the time being. The full title is A-V Instruction Materials and Methods, McGraw-Hill Co., 1959. Price $7.95.

(3) The Two Ends of the Log (Learning and Teaching in Today's College), edited by Russell M. Cooper, published by University of Minnesota Press, Minneapolis, 1958. Price $4. (Includes Chapters on A-V methods and TV in teaching.)

(4) They See What You Mean, a transparency process handbook published by the Ozalid Company, Johnson City, N. Y., 1959. Price $3.75.

(5) Diazo Materials Catalogs from the following: Tecnifax Corp., Holyoke, Mass.; Charles Beseler Co., East Orange, N. J., and the Ozalid Co., at Johnson City, N. Y.

(6) Teaching Machines and Programmed Learning: A Source Book, edited by A. A. Lumsdaine and Robert Glaser, published by the Department of Audio-Visual Instruction of the NEA, 1960. Price $1.50.

SCHEDULE OF WORK SESSIONS
Technology and Improved Teaching

Carlton W. H. Erickson
The University of Connecticut

and

Edward J. Rising
State University of Iowa

Session No. 1

HOW TO TEACH WITH MOTION PICTURES
Meeting Room A, 8:00 - 9:25

Session No. 2

HOW TO MAKE CLASSROOM ARRANGEMENTS FOR PROJECTION
Meeting Room A, 9:25 - 9:50

Refreshments, 9:50 - 10:10

Session No. 3

HOW TO MAKE YOUR OWN NON-PHOTO SLIDES AND OVERHEAD TRANSPARENCIES
Meeting Room A, 10:10 - 12:00

LUNCHEON

Session No. 4

FITTING AUDIO-VISUAL MATERIALS INTO TEACHING PLANS
Meeting Room A, 1:00 - 2:25

Session No. 5

A DEMONSTRATION OF POLAROID, SINGLE LENS CAMERA, AND CONTOURA-CONSTAT COPIER SYSTEMS
Meeting Room B, 2:25 - 3:55

Session No. 6

TEACHING MACHINES: TECHNOLOGY'S LATEST CONTRIBUTION
Meeting Room A, 3:55 - 5:00

GG2

TEACHING WITH MOTION PICTURES

Guide Sheet for Group Action

Pennsylvania State University Engineering Seminar

September 2, 1960

Time: 8:00 - 9:25, Session 1, Room A

Creative Decisions for Effective Film Utilization

Questions:

1. How can you locate such films as were just shown?

   ASEE Journals and Handbooks
   Published film sourcebooks (See Chapter 3 of Reference)
   Univ. Film Library catalogs
   Free-film source lists (Guide to Free Films, Educators Press, Randolph, Wisconsin.)

2. Consider first Dr. Rising's film: "Engineering Computation Skills: The Slide Rule, #9, Raising Numbers to Powers."

   (a) What purposes (specific teaching objectives) ought you or could you have in mind for using such a film? Let's formulate some.

   Abilities to: (Kinds of valid, significant, practical performance that grow out of course activities and assignments.)

   (1)

   (2)

   (3)

   Understandings that: (Beliefs, conclusions, insights, concepts, key ideas, definitions, laws and directions for carrying out some procedure.)

   (1)

   (2)

   Attitudes of: (Stable mental sets showing up at work, play, home and church.)

   (1)

   (2)

   (3)

   Appreciations of: (Tendencies to like and choose something. Keep statements simple, brief, specific. Do not confuse with broader sets called attitudes. Do not confuse with understandings. Stick to characteristics and behavior, such as high quality tools, skillful planning, clear thinking.

   (1)

   (2)

   (3)

(b) What are some readiness plans that you could devise to start this film off properly?

(c) What student action is demanded by your purposes for this film? How will you get it? (Practice the procedures then apply them to practical problems. Class discussion of concepts, values. How check student accomplishment?)

3. Now let's recall for a few minutes the Mackinac Bridge Diary film sequence to answer some similar questions.

(a) How did you react to that sequence from the standpoint of engineering planning and processes?

(b) Could such a film be considered as a substitute for a field trip to actual construction sites?

(c) What abilities could the use of such a film help you as a teacher to develop? What technical understandings? Attitudes? Appreciations?

(d) What kinds of problems ought to be presented before such a film were shown.

(e) Why should teachers set up problems before and/or after films?

(f) How would you introduce such a film in your class? (How get students ready for it?)

(Set up problems)
(Tell about the value of a visit to the famous bridge)
(Direct observation of students to key points)

(g) What possible value would there be in using this film as a springboard into a subject or course?

4. Next let's consider the Torque Converter film:

(a) Do films often provide experiences with large and complicated models and specialized equipment?

(b) Can students sometimes see models in films better than if they were right in front of the room?

(c) Just what should teachers do after showing a film like the Torque Converter?

(d) What determines the problems and questions for discussion and for future assignments?

(e) Why do films stimulate interest?

(f) What do teachers need to say to introduce a film like this?

(g) Mention some thought-type questions that teachers should ask after this film.

GG4

CONTROL OF CLASSROOM ARRANGEMENTS FOR PROJECTION

Pennsylvania State University Engineering Seminar, September 2, 1960
Time 9:25 - 9:50, Session 2, Room A

Worksheet for Projection Practices

(1) Is the room portrayed by this diagram longer than wide? How do modern amphitheatre-type classrooms in colleges compare with this shape?

(2) What kind of screen would give the brightest picture for most of the students in the room shown by the diagram presented.

(3) What is the maximum recommended viewing angle for the glass-beaded screen?

(4) How does an aisle facilitate multiple projection?

(5) What arrangements of projectors are necessary when an aisle is not feasible because of fixed seats?

(6) Where should the first row of viewers be located with respect to a projection screen?

(7) What is the maximum distance for the last row of viewers?

(8) What is a rule of thumb for determining the size of screen needed in any given room?

(9) Under what condition should a matte screen be ordered? (Shape of room factor.)

(10) When should a square screen be specified in your request?

(11) What is the "keystone" effect? When does it occur? When is it serious? How can it be eliminated?

(12) How could my arrangements in this room have been improved?

One more major question remains to be answered if you are to function effectively with projected materials. It is this:

How are equipment operation problems usually solved?

(a) If projection services are available order them and explain specifically what you want to do. Take charge of the operators sent you. Arrange signals and tell them when you want the showing started, and if you do not want to be disturbed with re-winding, etc., say so, and agree on special arrangements. Know what projection arrangement is best for your room and be ready for action. For example move the desk into the aisle and have students placed for good viewing before the class starts and have windows partially darkened. These preparations avoid confusion and save time.

(b) If you have to operate the equipment yourself, procure the equipment and plan out what details have to be handled for an efficient presentation.

BRIEF INSTRUCTIONS FOR MAKING NON-PHOTO SLIDES AND SIMPLE HAND-DRAWN TRANSPARENCIES

Guide Sheet

Session 3, Room A, 10:10 - 12:00

General Plan:

The group is to be split into two separated working sections for this activity. One section will work on transparencies, the other on slides. Sections will alternate in their working stations at half-time. Instructors for each section follow:

Instructors for Slide-Making Group

1. Place black rectangular mask over drawing in the horizontal position and place etched glass, etched side up, on top of the mask.
2. Use soft lead pencil to trace firm black outline of drawing. (Or if you wish, make a free-hand drawing of your choice.)
3. Use crayons (sandpaper is for sharpening) to apply color up to the lead-pencil lines.
4. Make colors vivid by firm pressure and re-application.
5. When drawing is finished, put black mask on top of etched glass and place a piece of clear cover glass on top of mask. Pick up the assembled pieces as a unit, press together, even up the edges by pressing them down on the table top, then bind together with binding tape.
6. Bind firmly using a two-inch piece of tape for each edge of the slide. (This is the quick simple way to protect your drawing. Other methods like the passe partout or slide-vise method exist but we haven't the time to show or use them.
7. Put a small piece ($\frac{1}{4}$ inch square) of tape on the glass in the lower left hand corner of your bound slide as it lays on the table, drawing side up. This is the thumb mark. Now rotate your slide so this mark is in the upper right hand corner. Grasp the slide at the thumb mark and insert it in that position in the slide projector carrier as you face the screen.
8. Make more than one slide if time permits.

Instructions for Transparency-Making Group:

1. Place acetate sheet over large drawing, supplied at your table, centering it in either a horizontal or vertical position. (Enlarge the drawing by free hand methods, or use a drawing of your own that is needed in your teaching.)
2. Trace outline of drawing by using grease pencil with firm, solid lines.
3. If some areas or lines of color are desired, use one of the CADO MARKER felt-nib pens. (Only a few sets are available here today.)
4. Use more than one layer of acetate if you wish, but be sure to keep all sheets used in perfect register. (That is, split your drawing into several parts planning to present one part at a time.)

5. Fasten single drawings to mount board by using transparent non-bleeding tape (3M, No. 810). Put a strip of tape along each edge.
6. Tape dispensers are not available here, so use one of the scissors to cut off pieces of tape.
7. If you are using more than one acetate layer, fasten extra layers at one side or at the top edge, only.
8. Take your slide to the 10" x 10" overhead projector and project it.
9. Make another drawing if you have time.

THE LABORATORY IN ENGINEERING EDUCATION

Edward R. Schatz
Carnegie Institute of Technology

It is the purpose of this introductory material to set the stage for a discussion of laboratory instruction. The plan for the session is to follow the outline, which is proposed below, in examining the various facets of laboratory instruction as it is now carried out at several schools, and to propose objectives and procedures for the laboratory which are consistent with and advance the over-all objectives of engineering education discussed and defined at earlier sessions of the Institute. A further objective for this session is to examine the purposes and functions of the laboratory in the light of information presented at prior meetings on theories of learning and techniques of teaching.

The outline below includes information and key topics on which discussion might be started. The suggestions made under each heading are not meant to be complete or, even, to be consistent. The ideas have come from various sources such as college catalogs and educational journals. Each numbered item is submitted for consideration as an aim or a procedure or an example. References are also made where possible and helpful to the literature.

I. PHILOSOPHY OF ENGINEERING LABORATORY INSTRUCTION

1. ". . . . there is no absolute necessity for using laboratory instruction in any particular course, nor even an absolute minimum of necessary laboratory instruction in the electrical engineering curriculum. Laboratory space and equipment are expensive. We should only use a laboratory activity if it will attain an educational objective more efficiently than by other means." Objectives and Conduct of a Problem-Solving Laboratory in Electrical Engineering Science, E. M. Williams and F. J. Young, 1959 Sagamore Conference on Electrical Engineering Education (not in published form; will be supplied.)

2. "Laboratory experience should be a part of the program, for it serves the following purposes:

    a. Exercises which confirm theoretical concepts and the laws discussed in formal classrooms give the student a feeling of confidence, a conviction that the statements presented are truths.

    b. The laboratory experiences enable the student to see how well his ideal system predicts the operation of an actual system.

    c. By means of suitable experiments the student is afforded many opportunities to develop facility in the use of measuring instruments of all types.

    d. Many students entering university work have had little opportunity to observe actual engineering devices in operation. The laboratory affords them a chance to make such observations under expert guidance.

    e. By proper arrangement of student participation, the laboratory gives the student actual experience in managerial and organizational procedure. Student leaders who are responsible for the planning of the group derive a great deal of value from their experience.

    f. The laboratory serves as a means by which the student develops skill in both analysis and synthesis.

    g. Oral and written reports enable the student to gain additional facility in the use of the languages of engineering."

A Philosophy of Engineering Education, J. Stuart Johnson, Journal of Engineering Education, Vol. 49, 1958-59, pp 580-587.

3. "a. Laboratory instruction is vital to the presentation of the technical content of an engineering curriculum.

    b. Laboratory instruction should be considered as an integral part of a course and not as a separate course.

    c. The instructor is the most important factor in the successful presentation of laboratory work and he should receive suitable recognition.

    d. The amount of laboratory report writing done by the student should be kept within reasonable limits and emphasis should be placed on quality rather than on quantity."

Laboratory Instruction in an Engineering Curriculum, N. C. Ebaugh, Journal of Engineering Education, Vol. 38, 1947-48, pp 659-662

4. "In searching for fertile ground in which to cultivate the thinking processes, the laboratory should not be overlooked. Here good pedagogical practice would certainly call for the elimination of the "cook-book" variety of experiment in which the student is presented

with step by step instructions to guide him, as a German shepherd dog leads the blind, through every physical manipulation and mathematical calculation. Instructions should be minimized.

"In many cases, it might be feasible merely to present the problem and call upon the student to devise his own method of conducting the experiment. In physics, for example, a student might be given a block, a plane, some weights, and a spring balance and asked to study the laws of friction. Naturally, the student would have many questions to ask, and that is good. It might possibly indicate that he is thinking!"

How Can We Encourage Engineering Students to Think, Robert A. Janke, Journal of Engineering Education, Vol. 48, 1957-58, pp 34-38.

5. "Laboratory furnishes one channel by which knowledge can be acquired, supplements other teaching methods, and is particularly useful where mathematical descriptions are imperfect. In addition, laboratory deals with precision measurement, data recording, development of mechanical aptitude, and learning of specific techniques. Coordination of laboratory with other work usually follows one of two conflicting principles. A laboratory course may be conducted in a rigid manner or in a highly individualistic, flexible way. Each has its advantages. Laboratory provides good practice for report writing. By requiring at least one formal paper per student on laboratory work performed, a more realistic introduction to report writing is secured than in any other course work."

Laboratory: Its Scope and Philosophy, R. F. Schwartz, IRE Transactions on Education, Vol. #-2, No. 4, Sept. 1959, pp 120-122.

6. "The laboratory program has undergone significant changes--it has been removed from a secondary position in the lecture program and reconstituted on an equal level with the lecture courses in the new program. These changes have resulted in an electrical engineering curriculum which is challenging and up-to-date in all respects.
"The 'old program' consisted on a one-year course in the fundamentals of electrical engineering and the equivalent of three full-year courses in advanced topics of electrical engineering.

"The experiments performed in the laboratory associated with any one course were designed to back up, in a practical manner, the lecture material of the course. The laboratory program was as effective as any such program could be, but it lacked the depth necessary to motivate the student to complete involvement in the laboratory work.

"The 'new program' consists of lecture courses and laboratory courses designed to develop fully the technical background of the electrical engineering student in the important fields of electrical engineering. The laboratory experiments are no longer intended to re-emphasize the lecture material but are designed to build on the lecture material, and thereby to develop new concepts. Thus, subjects which are best suited to a lecture-type presentation are covered in the lecture courses and subjects which are most appropriate to an experimental development are covered in the laboratory courses."

A Look at the New Electrical Engineering Laboratory Program at the Hopkins, Theodore A. Bickart, IRE Transactions on Education, Vol. E-3, No. 2 June 1960, pp 36-41.

7. "The engineering laboratory is an excellent place for the student to gain experience in leadership."

Student Leadership Training in the Laboratory, Raymond C. Hall, Journal of Engineering Education, Vol. 50, No. 5, 1959-60, pp 415-417.

Additional references:

8. Engineering Laboratory Courses, J. N. Thurston, Journal of Engineering Education, Vol. 44, 1953-54, pp 421-422.
9. The Purpose and Character of Laboratory Instruction, David J. Blick, Journal of Chemical Education, Vol. 32, May 1955, pp 264-266.
10. Functional Laboratory Courses, N. P. Bailey and J. J. Devine, Journal of Engineering Education, Vol. 38, 1947-48, pp 141-143.
11. Role of the Laboratory in Engineering Education, Ronald L. McFarlan, IRE Transactions on Education, Vol. E-2, No. 1, March 1959, pp 23-27.

II. BROAD OBJECTIVES OF ENGINEERING LABORATORY INSTRUCTION

1. "The objectives of the laboratory are to help the student:
   a. Learn to visualize engineering concepts in terms of physical operations;
   b. Understand the extent of agreement between theory and experiment and the effect of assumptions that are inevitably made;
   c. Learn to plan and execute experiments;

d. Become familiar with a few pieces of standard laboratory equipment and learn a few classical techniques;

e. Learn to share responsibility and cooperate with his peers in effective teamwork."

Objectives in Engineering Education, B. R. Teare, Jr., 1960 Summer Institute for Engineering Teachers.

2. "Problem-Solving Objectives of the Laboratory:

   a. Learning to use the laboratory as a tool in problem-solving;

   b. Enhancement of a responsible attitude in problem-solving;

   c. Development of understanding of the role of simplifications and derived concepts in relation to problem-solving and basic-science, and consequently, reinforcing of the student's comprehension of basic science;

   d. Encouragement of initiative and inventiveness."

   (See reference under Item I-1)

3. "There are some objectives of an engineering training which can be accomplished better in the laboratory than in the classroom. These are:

   a. To teach the use and limitations of instruments for measuring pressure, temperature, time, speed, area, heat of combustion, humidity, current, voltage watts, power factor, stress, strain, work, etc.

   b. To widen the student's acquaintance with engineering equipment.

   c. To acquaint the student with the various test codes used in professional practice which have been developed by our professional societies.

   d. To teach the engineering method of selecting and using instruments, equipment, and men for accomplishing a specific task in the field of research, design, or testing.

   e. To give training and practice in the preparation of engineering reports."

   (See reference under Item I-3)

4. "Many laboratory manuals state that the purpose of laboratory instruction is to bring the student into actual contact with the material studied. This enables the student to obtain a knowledge of the subject that mere study alone cannot furnish. Other contributions of laboratory work frequently listed are: development of manipulative skill, development of self-reliance and ingenuity, training in the accuracy of measurement and the interpretation of experimental data, training

in the writing of satisfactory reports, satisfaction of curiosity, and the cultivation of scientific attitudes and an appreciation of scientific method through experimental investigation."

(See reference under Item I-9)

III. PLANNING AND DESIGN OF LABORATORY COURSES AND ASSIGNMENTS

Learning Aspects:

1. "Students learn first and foremost from what they do, not by what they are told. If a student conducts a particular test in accordance with detailed instructions, he is most likely to learn (a) to follow instructions and (b) a ceremony for conducting a particular test. When directed to make specific observations, he will unfailingly learn (c) to follow instructions and (d) the observations to be expected in a particular test."

   (See reference under Item I-1)

2. "Laboratory work in its broad sense implies 'learning by doing.' Certainly this concept is in accord with the currently accepted theories of learning and has a good psychological foundation. However, it is important to remember that laboratory work should be conceived as a means to an end and not as an end in itself. . . .

   "Unfortunately, much laboratory work is conducted on the basis of the deductive-descriptive approach as represented by the typical laboratory manual. In the deductive approach the student starts with a principle and makes observations or performs experiments to verify what is already known. All too often the student can complete the exercise more accurately outside the laboratory. And unknowingly, instructors may be encouraging intellectual dishonesty by demanding too precise results.

   "In contrast to the deductive-descriptive, the inductive-deductive approach implies the use of observed data to arrive at a more general principle which is then used in solving specific problems."

   (See reference under Item I-9)

Teaching Aspects

3. "Strategy for problem-solving laboratory:

   "A. In the first place, each problem is new to our students. A particular problem may be assigned concurrently to all the students in every section of a course, but once a solution has been completed, each problem is never used again.

"B. In the second place, the execution of each problem follows a prescribed timing. The students receive the problem statement about two weeks in advance of the laboratory period in which laboratory work on the problem will be initiated. The students will work in groups in the laboratory but are individually required to present, about a week before the beginning of the laboratory work, a plan for the solution of the problem, with (1) all preliminary analytical work (2) a statement of how they expect to proceed in the laboratory and with what tools and (3) a statement as to how they will use the data obtained. This plan is graded and returned to the student at least one day in advance of the beginning of the laboratory work.

"C. Thirdly, although there may be preliminary treatment of the problem such as that involved in the advance grading of plans, before the initiation of laboratory work, this treatment is not permitted to destroy the students' initiative. Instructors' comments on a laboratory plan, for instance, may point out scientific fallacies, ask leading questions, etc., but do not give corrected procedures. Students who ignore the implications of these comments may enter the laboratory with incorrect plans and are permitted to proceed in an erroneous manner.

"D. Finally, there is no thought on our part that one laboratory period will suffice for the completion of the laboratory phases of a particular problem solution. Generally, at least two periods are required and occasionally three."
(See reference under Item I-1)

4. "Experiments or problems are proposed to the students about a week or ten days before they are begun in the laboratory. In the interval, student groups (of three) are required to produce plans, about 6 to 8 pages in length, detailing the theory of the experiment and the procedures to be followed. All component values, pulse rates, etc., must be specified with the reasons for their choices. After the instructor has inspected these plans, a class period is spent discussing the problems involved. Formal lecture material, which is usually necessary to coordinate the work and discussion, is not allowed to anticipate the student's first studies of the problem. The experiment is concluded by the writing of a report by each group before proceeding to the next problem."

A Senior-Year Semiconductor and Electron Device Course, A. G. Milnes, IRE Transactions on Education, Vol. E-2, No. 1, March 1959, pp 6-9.

5. "Just as correlation of laboratory and classroom work varies greatly among various schools, there is also a great deal of variation on the exact method by which laboratory courses should be organized and taught. One extreme is to make laboratory period short and frequent with the instruction for each experiment so specific that the student can attain some limited objectives in the allotted time. In this type of course, even the items of equipment to be used are often specified. Outside work is discouraged or even forbidden. The advantages are that the student always knows what to do; he can develop good (though fixed) work habits; his results are usually consistent; and the instructor has an easy correcting job. The disadvantages are, that for the student to obtain breadth of knowledge, he must do a great many experiments, and he may become so conditioned by being told what to do as to be in a mental straitjacket.

   "The other extreme is a laboratory course which might be called the project type. The periods are usually longer. Sometimes the hours are not even fixed. The student is only told what is wanted, not how to do it. Procedure, equipment, and method of recording data left to him. The advantages of this method are apparent only in "good" students since many cannot rise to the demands imposed by such a course. If a student can get into the spirit of this philosophy, and if he can develop an inquisitive attitude, he can learn far more than by the first method. However, it can be extremely difficult for the instructor to evaluate and grade the results.

   "In the opinion of this writer the optimum laboratory program is one which starts with the first philosophy and moves continuously toward the second. At the start, let us say, of the sophomore or early junior year, good work habits could be established, but, by demanding slightly more initiative and imagination of the student in each succeeding experiment, he would be led to the point where he was capable of independent thought."

   (See reference under Item I-5)

6. "We now come to the all-important subject of coordination between classroom and laboratory. If the idea of learning the same thing by several different methods has any validity, there must be at least a certain amount of close coordination between classroom teaching and laboratory. It appears desirable to have the basic underlying principles understood

before doing laboratory work. The laboratory instructor has enough to do without having to delve into the details on the derivation of a particular equation. If curriculum problems prevent the necessary theory work from preceding laboratory work, it would seem desirable to have at least the two run concurrently.

"There are two interesting and contradictory ideas on this subject. The first is that theory instruction and laboratory instruction are part of the same process of education, the teaching of different aspects of the same thing. According to this, there should be no time lag between the two.

"The second idea is that if knowledge is imparted two or more times at suitable intervals, it will become better fixed in the mind than if the exposure occurs only once. It is almost as if the first exposure conditions the mind for being receptive after a proper interval to more information on the same subject. Under this scheme, laboratory should follow the theory work by seven to fourteen weeks.

"Beside coordination of laboratory and classroom work, it is also necessary to coordinate one laboratory course with the next, so that unnecessary duplication is avoided. A number of schools have found that the appointment of one person to oversee, but not necessarily teach, all laboratory work can resolve this problem."

(See reference under Item I-5)

Additional references:

7. Increase Laboratory Effectiveness with Greater Student Participation, T. H. Rockwell, Journal of Engineering Education, Vol. 48, 1957-58, pp. 39-42.
8. Undergraduate Laboratories--Some Comments on Efficient Use of Student's Time, W. J. Fahey, IRE Transactions on Education, Vol. E-2, No. 3, June 1959, pp 75-77.
9. Methods of Chemical Engineering Laboratory Instruction, R. K. Toner, Journal of Engineering Education, Vol. 38, 1947-48, pp 745-750.
10. Conference Method in Laboratory Courses, J. E. Gibson, Journal of Engineering Education, Vol. 45, 1954-55, pp 540-541.
11. Aspirin for a Teaching Headache, H. E. Johnson, Journal of Engineering Education, Vol. 47, 1956-57, pp 456-458.

IV. EXAMPLES OF LABORATORY ASSIGNMENTS

(In this section reference will be made to examples in the published literature. Other examples will be included at the session on laboratory.)

1. A Laboratory Problem Centered "First Course" for Electrical Engineers, F. J. Young and E. M. Williams, 7th Regional IRE Conference, Albuquerque, New Mexico (Paper to be supplied)
2. A Look at the New Electrical Engineering Laboratory Program at the Hopkins, T. A. Bickart, IRE Transactions on Education, Vol. E-3, No. 2, June 1960, pp 36-41.
3. A Senior-Year Semiconductor and Electron Device Course, A. G. Milnes, IRE Transactions on Education, Vol. E-2, No. 1, March 1959, pp 6-9.
4. A Combined Machinery and Control Systems Laboratory, W. A. Blackwell and H. E. Koenig, IRE Transactions on Education, Vol. E-2, No. 4, Sept 1959, pp 128-134.
5. Laboratory Demonstration Experiment--A Link between Fundamentals and Applications, D. Rosenthal and H. Baer, Journal of Engineering Education, Vol. 41, 1950-51, pp 171-175.
6. Laboratory for Mechanical Engineers, J. J. Ryan, Journal of Engineering Education, Vol. 38, 1947-48, pp 235-238.
7. A Plea for the Simple Experiment, R. Lemlich, Journal of Engineering Education, Vol. 48, 1957-58, pp 385-386.
8. "Two-Penny" Experiments in Chemical Engineering, R. Lemlich, Journal of Chemical Engineering, Vol. 34, No. 10, Oct. 1957, pp 489-491.
9. A Materials Testing Laboratory, C. W. Richards, Journal of Engineering Education, Vol. 48, 1957-58, pp 562-567.
10. UCLA Laboratory Program:
    1. Introduction to Engineering Systems
    2. Introduction to Design
    3. Introduction to Engineering Materials
    4. Introduction to Engineering Processes

    Freshman and Sophomore years

    5, 6, 7, 8. Experimental Engineering - Junior, Senior years. (See UCLA catalog)

V. OTHER ASPECTS

1. Optimum Use of Equipment
2. Instructors for Laboratory
3. Cost of Laboratory Equipment

TESTS AND EXAMINATIONS USED FOR PROMOTING LEARNING

Robert L. Ebel

Educational Testing Service

An Outline of Ideas for Elaboration and Discussion
at the
Institute on Methods of Teaching for New Engineering Teachers

I. The Functions of Measurement

A. All the functions of educational measurement are concerned either directly or indirectly with the facilitation of learning.

B. The principle functions of educational achievement tests produced by classroom teachers are:

1. To measure achievement, as a basis for school records, reports to parents, evaluation of progress, and decisions on future plans.
2. To define educational objectives in operational terms.
3. To motivate and direct study and teaching.
4. To facilitate research on educational problems.
5. To provide effective instructional exercises.

C. The educational value of an examination is dependent almost entirely upon its quality. Good examinations have beneficial effects. Bad examinations are harmful. A good examination is one which:

1. Is fair to the course, in view of the things the course is supposed to teach.
2. Is fair to the students, in view of the instruction given them.
3. Makes efficient use of the instructors limited time for preparation and grading, and of the students' limited time in the examination period.
4. Emphasizes important, long-run achievements more than incidental, quickly-forgotten information.
5. Is administered under conditions which give each student a good and an equal chance to demonstrate his achievements.
6. Is composed of questions which are individually effective in distinguishing between good and poor students.
7. The questions are of appropriate difficulty, neither too hard nor too easy.
8. Distinguishes clearly between students at different levels of ability.
9. Yields reasonably reliable scores which would agree closely with those from another equivalent test.
10. Is appropriate in length for the time available--long enough to give reliable scores but short enough so most students have time to attempt all items.

D. Examinations help teachers to clarify their objectives.

   1. A good test of educational achievement measures as directly as possible as many as possible of the ultimate objectives of instruction in the course.
   2. Many educational objectives sound impressive, but are difficult to define in meaningful terms.
   3. An educational achievement test can provide an operational definition of the objectives in a course.
   4. No quality which persons or things have more or less of can be studied effectively or described meaningfully unless it can be quantified.
   5. No quality can be quantified until it has been operationally defined.
   6. Carefully constructed examinations can provide useful indications of the general competence of a teacher.

E. Examinations can motivate and direct the process of study and teaching.

   1. Examinations provide a powerful incentive to study, and influence pupil emphasis in study.
   2. The value of a good examination accrues to a considerable degree before it is given.
   3. In order for examinations to exert optimum influence on study and teaching, they should be made out before the course begins, and their general nature should be described to the students.
   4. Educational experiments reveal that students who are aware of the progress they are making tend to make more progress than those who are not.
   5. Examinations help the teacher to individualize instruction by identifying the particular capabilities and deficiencies of individual students.
   6. Examinations can help to adapt instruction to class needs by identifying the general class ability level and particular topics or areas of instruction which need emphasis.

F. Examinations provide effective instructional exercises.

   1. Students work hard in taking a test, tend to remember their successful answers, and attempt to correct the deficiencies they discover in their abilities.
   2. Teaching machines, such as those developed by B. F. Skinner, programmed learning textbooks, such as those developed by Norman Crowder and others use testing as the basic means of teaching.
   3. An elaborate testing device developed for the selection of school administrators has been used effectively in the training of school administrators.
   4. Much effort to learn through reading and listening is ineffective because the minds of neither the instructor or the student are focused on problems to be solved, and no rewards are granted or withheld on the basis of effective or ineffective thinking.

G. Examinations help teachers assign more reliable and more valid grades.

1. Grades are important. There is nothing "mere" about the process or consequences of assigning grades.
2. "Working for a grade," and "working to get the most possible out of a course," are identical goals if the grading process is properly handled.
3. It is illogical to argue that grades are evil simply because grading has been badly done. A constructive solution is to improve the quality of grades.
4. Parents, employers, and college admissions officers rely heavily on grade records.

II. Planning the Test

A. Decide when to test.

B. Decide what kinds of questions to use.

C. Decide how many questions to include in the test.

D. Decide what emphasis to give to various aspects of achievement.

E. List the units to be covered and the question topics to be used so that a representative sample of the students' capabilities will be obtained.

F. Decide what level and distribution of difficulties is appropriate for the questions included in the test.

G. Decide whether, and if so how, to determine the passing score on the test.

III. Grades and marking systems

A. Are grades necessary?

B. Should each instructor conform to institutional policies in grading?

C. Is "grading on the curve" justified?

D. Is it justifiable to give more high grades in advanced courses or in courses which enroll especially capable students?

E. Should grades be regarded as measures or as evaluations?

F. Should grades reflect a students' attitude, effort, and amount of improvement, or simply the level of achievement he has reached?

G. Is the present general system of grading, making use of five letter grades, the best that can be devised?

H. How can numerical scores be converted into stanines or letter grades?

1. Divide the distribution of scores into three parts: an upper part containing slightly less than one fourth of the scores (23% exactly), a middle part containing slightly more than one half of the scores (54% exactly) and a lower part containing slightly less than one fourth of the scores (23% exactly).

2. Divide the middle part into three nearly equal raw score intervals. If they cannot be exactly equal, make the middle interval one unit larger or one unit smaller than the other two. These three intervals define stanine scores of 4, 5, and 6.

3. Extend the same pattern of interval sizes upward to define stanine scores of 7, 8, and 9. Extend them downward to define stanine scores of 3, 2, and 1.

4. It is possible, but somewhat less desirable, to assign stanine scores on a percentage basis, according to this table:

Stanine Score	Percent of Scores
9	highest 4%
8	next 7%
7	next 12%
6	next 17%
5	next 20%
4	next 17%
3	next 12%
2	next 7%
1	lowest 4%

5. Final grades should be based on totals of weighted raw score units, not on averages of letter grade "points," stanine scores or other converted scores which are less precise than the original raw scores.

6. The weight a given set of scores carries in determining the final mark is determined by its variability (standard deviation).

7. A similar process can be used for converting numerical scores into letter grades, except that the upper and lower parts include only 7% of the scores and are not further subdivided. Scores in the upper part receive a grade of A; those in the lower part a grade of E. The middle part is subdivided into three intervals, as nearly equal as possible, and scores in these intervals receive grades of B, C, and D respectively. The ideal percentage distribution of marks under this system is A - 7%, B - 24%, C - 38%, D - 24%, E - 7%.

8. The temptation to determine mark intervals by looking for natural "breaks" in the distribution is strong, but ought to be resisted. Such breaks are largely chance occurrences, and tend to destroy the equality of the intervals.

9. Example of score conversion to stanines:

a. Scores 112 109 106 105 104 100 97 97
95 95 93 91 90 89 84 84 83 82
81 80 78 75 75 75 74 72 71 70
69 68 66 62 59 59 58 51 47 44

b.

Upper part	(9 scores)	95-112
Middle part	(20 scores)	69-95
Lower part	(9 scores)	44-68

c. Middle intervals $\frac{95 - 68}{3} = 9$

69 - 77, 78 - 86, 87 - 95

d.

Stanines	Intervals	Frequency
9	114-122	0
8	105-113	4
7	96-104	4
6	87-95	6
5	78-86	7
4	69-77	8
3	60-68	3
2	51-59	4
1	42-50	2

IV. Other Types of Tests

A. Oral examinations have severe limitations but may be useful in some special situations.

1. Oral examinations are time consuming for the examiner since, ordinarily, only one student can be examined at a time.
2. It is difficult to standardize examination conditions and questions for all examinees so that it is equally fair to all.
3. Irrelevant reactions and interactions of examiner and examinee are likely to bias the evaluations made.
4. Subjective judgments by examiners of examinee ability and potential have typically shown little validity.
5. The oral examination is not typical of situations in which the student will perform later. Hence the examinees performance in it may not be highly relevant to his real capabilities.
6. Oral examinations may have useful by-products in the revelation of personal traits of the examinee.
7. The oral examination is highly flexible.
8. With constant interaction of examiner and examinee, the oral examination can provide good learning opportunities.

B. Open book examinations have some merits, but other apparent advantages may be more apparent than real.

1. An open book examination encourages the examiner to ask application-type questions rather than recitation-type questions.
2. An open book examination encourages the student to study for understanding rather than for memory.
3. Unless test time limits are generous, the practical value to the examinee of free access to reference books may be small.
4. An open book examination may seem to be more typical of on-the-job situations, than is the usual type of examination. However, it seems probable that most of a person's decisions and actions are guided by what he carries in his head, not what he can look up in a reference. Hence the conventional examination may be in fact somewhat more relevant to usable abilities.

C. Take-home examinations have limited value as measurements because of opportunities for outside assistance, but provide extremely valuable learning exercises, especially if outside assistance is available and used.

HOW CAN EXAMINATIONS BE USED TO PROMOTE LEARNING?*

The appropriate use of good examinations can promote learning in at least four ways: first, by stimulating teachers to clarify their objectives; second, by motivating students to apply themselves to the learning task; third, by directing the efforts of students and teachers toward the attainment of essential achievements; and fourth, by providing effective learning exercises. This statement will be devoted mainly to a discussion of these four uses of examinations.

Before proceeding, however, it should be recognized that the discussion assumes that examinations can be used to promote learning. Not all professors would grant this assumption willingly. Some would hold that examinations actually impede learning, preventing students and teachers from cooperating effectively. Others would argue that the time students and teachers spend preparing for, taking, and grading examinations could be more profitable spent in other educational activities. Quite obviously the validity of these objections to the use of examinations depends at least partly on the quality of the examinations used. Bad examinations, or any examinations badly used, can certainly be harmful. On this point there need be no disagreement. But it would be wrong to apply this conclusion to any use of any examination. Good examinations, properly used, can contribute substantially to the educational enterprise.

What is a good examination? For the professor who uses examinations to measure the achievement of his students, a good examination is one which measures as directly as possible as many as possible of the ultimate objectives of achievement in his course. To measure ultimate achievement directly it must require the student to demonstrate command over the knowledge he possesses--to show that he can use it to solve problems, reach decisions, support recommendations, or make evaluations. It must not reward the student for mere possession of knowledge, or for ability only to recall words that he has read or heard.

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*The substance of this paper was presented at a Conference on College Teaching at the University of Minnesota on April 17, 1958. It was published in The Two Ends of the Log, Russell M. Cooper, ed., University of Minnesota Press, Minneapolis, 1958.

The proper use of classroom examinations is to promote learning. We have already mentioned four ways in which this can be done. Let us consider the first use mentioned--that of stimulating those who teach to define clearly their objectives for student achievement.

Most college professors tend to be somewhat impatient with requests from educationists that they state their course objectives explicitly. A chemistry professor I know told me once that his introductory course had only one objective--to teach the students some chemistry. A zoologist said that the purpose of his first course was to prepare for the second; of the second to prepare for the next; and so on until the student graduated. The assumption of these specialized scholars was that the essential objectives of their courses are so clearly inherent in the subject matter itself that attempts to abstract them verbally result only in a waste of time.

There is something to be said for this position. Certainly many definitions of educational objectives for elementary and secondary schools have consisted mainly of verbal platitudes or smoke-screens. In spite of the bast amounts of time and effort that have gone into the formulation of statements of objectives, it is difficult to point to specific educational advances which have resulted from many of them. One of the problems is that the concrete outcomes of learning in any course are multitudinous and diverse. Any statement which pretends to encompass all of them is inescapably abstract and general. Another problem is that most of these statements are the products of committees composed of competent, and therefore individualistic, individuals. To reach agreement they must propose statements which cannot be interpreted too clearly as supporting one point of view at the expense of others. The production of acceptable ambiguous phraseology which sounds impressively emphatic is a fine art. Some educators rival politicians in the practice of this art.

The fact remains that all teaching is guided by the purposes of the teacher and of those to whom he is responsible. Not all teaching is equally effective. Part of the difference between good and poor teaching certainly originates in differences between the objectives which guide the teaching: between purposeful and aimless teaching, between essential and trivial learning, between specific and indefinite goals of achievement. The professor who disdains concern for the objectives of the course he offers is deceiving either himself or those who employ his services.

If, as has been suggested, a good examination is one which measures the degree of attainment of the ultimate objectives of the course, then it is obviously impossible to prepare a good examination without careful consideration of objectives.[1,3,4,5] Conversely, and this truth is often overlooked, the examination when prepared provides a detailed, concrete, operational definition of the objectives. The real goals of achievement in the course are indicated by the tasks presented in the examination used to measure achievement. Guided by advance knowledge of the nature of these tasks, the efforts of teacher and student can be made more purposeful and hence more productive. The guidance will be as good as the test, and far better than can be obtained from any condensed general statement of abstract goals.

A second way in which examinations can promote learning is by motivating students to apply themselves to the learning task. Examinations provide powerful incentives to study. What a student studies is largely determined by what he expects to be tested on. How he studies is influenced by the kind of a test he expects. How hard he works depends in part on how soon he expects to be tested.

The motivating power of examinations is indicated by the cramming students do in the days and hours immediately preceding an examination. Cramming is generally disapproved, as it should be. Here again, however, it is not the use of examinations that should be blamed for undesirable cramming. The fault lies with the kind of examination which encourages cramming by rewarding it. If the examination requires detailed recall of limited areas of study, it will encourage and reward cramming. But if it requires the student to demonstrate command of useful knowledge by presenting him with novel questions or problem situations--tasks which require analytic and constructive thought as well as memory--cramming will be a waste of time. No student will be able to make a few hours or days of intensive review compensate for weeks of indifferent idleness.

The motivating influence of frequent tests has been the subject of numerous research investigations with somewhat equivocal findings.[9,10] In general these findings support the general principle that the educational influences of examinations depend on their quality and on the way in which they are used. If the examinations set up appropriate and reasonable goals for attainment, and if the student's performance on these examinations makes a real difference in his future opportunities, then the examinations do tend to stimulate effective learning.

A third use of classroom tests to promote learning is in directing the efforts of students and teachers toward the attainment of essential achievements. If the test which will be used to measure achievement is prepared before the course begins, and if the students are informed early about the kinds of achievement it will require of them, then the test will have a significant effect in directing the activities of students and teacher. Sometimes a test similar to the final test is used as a pre-test. This not only provides measures of initial status but also makes the students quite familiar with the general nature of the final test. Using the final test itself as a pre-test is not recommended, since it will tend to focus student attention on only a limited sample of the tasks which they should be prepared to handle. A test can direct student learning, but it does not provide a complete set of specifications for all that should be learned.

No one questions the fact that students tend to study the things they expect to be tested on, nor that teachers responsible for preparing students to take an external examination try to anticipate and stress the things their students will be expected to know. But many do question the educational value of this directive influence. They fear it will narrow the field of educational development, divert attention from important but not easily measured achievements, and impose an undesirable standardization of educational programs and products.

There is some basis for these fears, but again the degree of potential harm depends on the quality of the tests, and the way in which they are used. Tests can be used to widen the field of desired educational achievements. Teachers in many elementary and secondary schools have been encouraged to add instruction in the use of references and libraries by tests of study skills. Tests themselves do not set standards or impose requirements. Unless the scores on them are used blindly and mechanically, there is little danger of excessive standardization.

The type of examination also exercises a directive influence on educational efforts. There is ample research evidence that students do study differently in preparation for different types of examinations.[8,13] The problem-type tests widely used in engineering courses have a high degree of relevance to course objectives in most cases. Hence they are capable of guiding the educational efforts of students in the right directions, and probably do so in fact, in most cases.

Most teachers agree that an examination designed to reveal whether or not a student can use the knowledge he possesses is better than one which simply reveals whether or not he possesses it. Memory and recall are important, but selective recall and application are even more important. One good way of emphasizing the importance of ability to use knowledge is to give an open-book examination. The teacher who prepares such a test will tend to ask different--and better--questions than one who prepares the more conventional memory test. Students preparing for an open-book test will study differently--and more effectively--than in preparing for conventional tests. Open-book examinations deserve wider use in classroom testing than they have enjoyed thus far.

A fourth way in which examinations promote learning is by providing effective learning exercises. The process of taking a good examination is itself a valuable educational experience. Stroud[12] has suggested that the contribution made to the student's store of knowledge by the taking of an examination is as great, minute for minute, as any other enterprise he engages in. This will not be surprising to anyone who has observed the intense concentration of students taking an examination, in contrast to their relaxed and often semi-attentive attitudes during other phases of instruction.

The value of an examination as an instructional experience is enhanced if the questions are discussed after the examination has been marked. From the point of view of the psychology of learning, it is even better if the students can be informed as soon as they have marked a response whether or not it is the correct one. A number of devices such as the SRA Self Scorer, and the Neville Trainer-Tester have been used effectively for this purpose.

A similar, but far more elaborate and fundamental approach to learning has been made by Professor Skinner of Harvard[11]. He has developed a teaching machine to facilitate the occurrence of correct responses and to provide immediate reinforcement of them. Skinner points out that far greater progress has been made in the application of principles of learning to the conditioning of animals than to the education of human beings.

The Skinner machine presents a simple initial question or problem and requires the student to respond to it. It is intended to be simple enough so that he will almost certainly give the correct response to it. If he does, the machine moves on to the next problem which involves a slight extension of the idea involved in the first. Step by step, and with little direct involvement of a human teacher, the student extends the scope of his concepts and abilities. It is no simple task to organize the materials of instruction into a series of steps which the learner can follow with little or no outside assistance. But a great deal of progress has been made, and experimental work is continuing actively. The implications of this approach for the improvement of educational processes may be even greater than those associated with the use of television.

It has sometimes been suggested that test questions could be used as the starting point of fruitful class discussion.[6] The best items for this purpose would seem to be those which require reasoned application of knowledge to novel problem situations. Many test problems in engineering have this characteristic. Some objective tests, on the other hand, particularly those which have not had the benefit of expert development, tend to emphasize memory of isolated factual details rather than reasoned applications of knowledge. The contrast between these two types is illustrated in the sample multiple choice items on the next page. The correct answers to these questions are: 1. (B), 2. (C), 3. (A), 4. (B), 5. (C), 6. (C), 7. (D), 8. (B), 9. (B), 10. (A).

In general, the kinds of questions which provide the best basis for classroom discussion are also those which provide the best indications of the degree of attainment of the ultimate objectives of instruction in a course. Our tests should include many items of this type.

The preoccupation of this discussion with some of the more important direct values of examinations in the promotion of learning should not imply a disregard for other important indirect and long-term values of examinations when they are properly used for guidance, selection, placement and evaluation. This contradicts the view sometimes expressed that unless an examination has a direct and immediate influence in the improvement of learning it is a waste of time. The emphasis here on the direct contributions of examinations to learning should not minimize our interest in or appreciation of other appropriate uses of examinations in the educational enterprise.[2, 7]

Two things are primarily responsible for the considerable cultural lag in applying what we know about examining to the improvement of education. One is the conditioned antipathy of many people toward examinations. The taking of even a good examination is seldom regarded as a pleasant pastime. Most of us have been exposed to so many poor examinations, which provided invalid indications of achievement and formed a basis for unfair decisions, that our tendency to dislike them is easy to rationalize. This attitude can best be overcome by the development of skill in making better examinations, and in making wiser use of them.

The second factor responsible for this lag is the folklore prevalent among many college instructors that anyone who knows enough about a subject can teach it. This leads them to regard the special training in techniques of education provided by teachers' colleges and graduate schools of education as unnecessary or even positively harmful. Unfortunately, there is a good deal of fluff in many of the courses and curricula designed for the preparation of teachers. But this should not drive any reasonable person to the unreasonable conclusion that one can become a skilled teacher without studying how to teach. Doctors study the practice of medicine and surgery as well as biochemistry and anatomy. Lawyers study the practice of law and courtroom techniques as well as the corpus of the law. Dentists, more perhaps than either of the other groups, concentrate on developing skill in the practice of their special branch of knowledge. Someday, we may hope, a similar recognition will be given to the importance of specifically preparing college teachers to practice the techniques of their craft, and truly respectable programs for the training of college teachers will be adopted.

ILLUSTRATIVE MULTIPLE CHOICE TEST QUESTIONS

Factual Questions

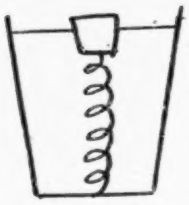
1. What is the technical definition of the term production?
   (A) Any natural process producing food or other raw materials.
   (B) The creation of economic value.
   (C) The manufacture of finished products.
   (D) The operation of a profit-making enterprise.

Reasoning Questions

2. Should merchants and middlemen be classified as producers or non-producers? Why?
   (A) As non-producers, because they make their living off producers and consumers.
   (B) As producers, because they are regulators and determiners of price.
   (C) As producers, because they aid in the distribution of goods.
   (D) As producers, because they assist in the circulation of money.

3. Whose name is given to the principle which helps to explain the behavior of floating bodies?
   (A) Archimedes
   (B) Aristotle
   (C) Buoyant
   (D) Newton

4. In a beaker almost full of water a cork is nearly submerged by the pull of a spring. If the beaker is allowed to fall free, what will happen to the cork during the period of free fall?



   (A) It will stay nearly submerged.
   (B) It will submerge completely.
   (C) It will float higher in the water.
   (D) It will alternately submerge and rise out of the water.

5. What is the product of 5 times 3?
   (A) 1 2/3
   (B) 8
   (C) 15
   (D) 35

6. If jelly beans come in five colors, how many beans must a child buy in order to be certain of getting three beans of the same color?
   (A) 3
   (B) 7
   (C) 11
   (D) 15

7. The poem Hiawatha was written by the author of
   (A) Leaves of Grass.
   (B) Thanatopsis.
   (C) Israfel.
   (D) The Village Blacksmith.

8. Which of the following quotations has most of the characteristics of conventional poetry?
   (A) I never saw a purple cow;
   I never hope to see one...
   (B) Announced by all the trumpets of the sky
   Arrives the snow and blasts his ramparts high.
   (C) Thou art blind and confined,
   While I am free for I can see.
   (D) In purple prose his passion he betrayed
   For verse was difficult. Here he never strayed.

9. What cools an electric refrigerator?
   (A) A current of air circulating inside the refrigerator.
   (B) An expanding gas.
   (C) An insulated metal coil.
   (D) The flow of electricity through a low resistance wire.

10. If an electric refrigerator is operated with the door open in a perfectly insulated sealed room, what will happen to the temperature of the room?
   (A) It will rise slowly.
   (B) It will remain constant.
   (C) It will drop slowly.
   (D) It will drop rapidly.

HOW TO PLAN A COURSE EXAMINATION

The preparation of any examination requires a number of preliminary decisions. Some of these are not considered explicitly but are implicit in what have come to be regarded as normal procedure. Others which should receive direct attention are left to chance or contingency. The planning of an examination need not be an elaborate, laborious process. However, it is almost axiomatic that a little attention to these preliminary decisions is likely to improve a test substantially. Here, then, are some of the decisions which must be made, and some of the considerations which should influence them.

1. Decide when to test.

To some extent the frequency and times of classroom testing are determined by institutional regulations on marking and reporting. Most instructors find it necessary or advisable to test at least twice during a semester. Some give hour tests every three or four weeks. Tests given at shorter intervals can sample smaller units of instruction more intensively, but there is no limit to the amount of instruction that can be sampled by a single test, and no inherent reason why a test which samples a small unit intensively is better than a test which samples a large unit diffusely.

Frequent testing has the advantage of providing a more reliable basis for evaluation, and of keeping both instructor and students more currently informed of student progress. But preparing and scoring frequent tests could consume a large share of the instructor's time, unless he has a stockpile of good test questions. It might in extreme cases even encroach undesirably on time for class instruction. Too frequent testing could also lead to overemphasis on test-passing as a goal for study. However, it is probably safe to say that few classes are overexposed to good tests. Educational psychologists have long recognized the educational value to students of the process of taking a good test. The recent flurry of interest in teaching machines has advertised this value more widely.

If instructors had complete freedom of choice in scheduling their tests, most would probably choose a mid-morning hour. Some would prefer a mid-week day. This degree of freedom of choice is seldom available and there is little if any evidence or strong logic to support preference for a particular hour or day.

2. Decide what kind of questions to use.

The most commonly used types of test questions are the essay or discussion type, the objective or short answer type, and the mathematical problem type. The subject matter of engineering lends itself especially well to problem type examinations, and these are widely, if not almost universally used in engineering courses. Since there are situations in which either the essay or the objective type could be more effective than the problem type, a brief comparison of their characteristics may be useful.

To begin, let us dispose of some common misconceptions. It is not true that one type tests real understanding whereas another tests only superficial knowledge. It is not true that luck is a large element in scores on one type and nearly or totally absent in another. On the contrary, all three types can require much the same kind and level of ability, and if carefully handled can yield results of almost equal reliability. A good essay test or a good objective test could be constructed so that it would rank a group of students in nearly the same order as that resulting from a good problem test. But this is not to say that all three types can be used interchangeably with equal ease and effectiveness.

Relative to the objective test, both essay and problem tests are easier to prepare. But the objective test can be scored more rapidly and more reliably (unless special pains are taken) than either of the other types, particularly the essay type. Where very large groups of students must be tested, the use of objective tests generally permits a gain in efficiency with little if any loss in validity. But where classes are small, the efficiency advantage is in the opposite direction, and essay or problem tests should be preferred.

The problem type has the advantage of greater intrinsic relevance--of greater identity with on-the-job requirements--than either of the other types. Many superficial or purely academic questions have been included in essay and objective tests. But this fault could and should be avoided.

Neither essay nor problem type tests, because of the length and complexity of the answers they require and because these answers must be written by hand, can sample as widely as is possible in an objective test. Writing is a much slower process than the reading on which objective tests depend. It is sometimes claimed that ability to choose an answer is different, and less significant, than ability to produce an answer. But most of the evidence indicates that these abilities are highly related.

In considering the relative merits of essay, problem and objective tests it is important to remember that the only useful component of any test score is the objectively verifiable component of it, regardless of the type of test from which it was derived. To the degree that a test score reflect the private, subjective, unverifiable impressions and values of one particular scorer, it is deficient in meaning and hence in usefulness to the student who received it or to any one else who is interested in his ability or achievement.

In objective tests and problem tests there is often a good deal more objectivity than in essay tests. The student usually has a more definite task, and the reasons for giving or withholding credit are more obvious to all concerned. But it is well to remember that even the objective test is based on many subjective decisions as to what to test and how to test it. For the problem test there is an additional element of subjectivity in scoring which is not present in the objective test. How much credit to give for an imperfect answer, and which elements to consider in judging degree of perfection are often matters of spur-of-the-moment, subjective decision when scoring problem tests.

In the interest of useful measurement the examiner should seek, whatever test form he uses, to make his measurements as objective as possible. Each of us is a different person, living largely in a unique world created by his own special history of experiences. It is not surprising that we find it difficult to agree on perceptions, meanings, and values. But since the harmony of our relationships and the effectiveness of our common enterprises depends on agreement, it is important for us to establish as much identity as possible among ourselves in these perceptions, meanings and values. This is only another way of saying we need to be as objective as possible in all things, including the measurement of achievement.

In most cases teachers of engineering courses have wisely chosen to emphasize problem type questions. However, it is possible that the force of habit, and some unwarranted assumptions, may prevent some engineering teachers from using other types when they would be advantageous.

3. Decide how many questions to include in the test.

The number of questions to include in a test is determined largely by the amount of time available for it. Many tests are limited to 50 minutes, more or less, because that is the scheduled length of the class period. Special examination schedules may provide periods of two hours or longer. In general, the longer the period and the examination, the more reliable the scores obtained from it. However, it is seldom practical or desirable to prepare an examination which will require more than three hours.

For various reasons there is a growing trend to make tests short enough so that most students have time to attempt all questions when working at their normal rates. One reason for this is that speed of response is not a primary objective of instruction in most college courses and hence does not contribute valid indications of achievement. In many areas of achievement, speed and accuracy are not highly correlated. A second reason is that examination anxiety, severe enough even in untimed tests, is accentuated when pressure to work rapidly as well as accurately is applied. A third is that efficient use of an instructor's painstakingly produced test requires that most students respond to all of it. In some situations, speed tests may be appropriate and valuable, but these situations seem to be the exception, not the rule.

The number of questions that an examinee can answer per minute depends on the kind of questions used, the complexity of the thought processes required to answer it, and the examinee's work habits. The fastest student in a class may finish a test in half the time required by the slowest.

For these reasons it is difficult to specify precisely how many questions to include in a given test. Experience with similar tests in similar classes is the best guide.

4. Decide what emphasis to give to various aspects of achievement.

Educational achievement in most courses consists in acquisition of a fund of usable knowledge and in the development of ability to perform certain tasks. Knowledge can be conveniently divided into knowledge of vocabulary and knowledge about matters of fact. Abilities usually include ability to explain and ability to apply knowledge to the taking of appropriate action in practical situations. Some courses aim to develop other abilities, such as ability to calculate, ability to predict, etc.

A rather detailed analysis of educational objectives for student achievement has been published by Bloom[1] and his associates. Their taxonomy includes test items appropriate for each objective or category of achievement. Dressel[2] and his colleagues have published outlines of test content in terms of subject matter and pupil achievements, and also present illustrative items. These are instructive guides in planning classroom tests. They serve to broaden the test constructor's perspectives on what to test and how to test it.

But some of the words used to identify achievements are more impressionistic than objectively meaningful. Some categories of educational achievements are based on hypothetical mental functions, such as comprehension, analysis, synthesis, scientific thinking, recognition, etc., whose functional independence is open to question. Unless such categories are directly related to obvious characteristics of different types of test questions, it is somewhat difficult to use them confidently in planning a test or analyzing its contents. Occasionally, too, the specified areas of achievement are so closely related to specific units of instruction that it is difficult to regard them as pervasive educational goals. Hence a somewhat simpler analysis of achievements broader in scope and more clearly identifiable with specific test items, seems adequate for considering what to test in a classroom test.

A major weakness of many classroom tests is overemphasis on knowledge of matters of fact--sometimes rather trivial facts--at the expense of emphasis on explanations, applications, calculations and other evidences of ability to use knowledge effectively. The appropriate proportions of questions in each category will vary from course to course, but the better tests tend to be those with heavier emphasis on applications of knowledge rather than on mere ability to reproduce its verbal representations. But it is more difficult to write good application questions than reproduction questions, and unless the test constructor decides explicitly in advance what proportion of the questions in his test should relate to each specified aspect of achievement, and carries out his decision, his test may suffer.

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[1] Bloom, Benjamin S. and others, Taxonomy of Educational Objectives, Longmans Green, and Company, New York, 1956.

[2] Dressel, Paul L., Comprehensive Examinations in a Program of General Education, Michigan State College Press, East Lansing, Michigan, 1949.

5. List the units to be covered and the question topics to be used so that a representative sample of the student's capabilities will be obtained.

An item of information or an ability is appropriate to use as the bases for an examination question in a classroom test if it has been given specific attention in instruction. Intentional or inadvertent direct testing of things which were not taught or assigned for learning is hard to justify.

One approach to defining the appropriate universe for sampling is to list as topics the specific areas of knowledge and specific abilities toward which instruction was directed. In the simplest case, where instruction is based on a single text, section headings in the textbook may provide a satisfactory list of such topics. If these section headings should be three times as numerous as the questions needed for a final test, the instructor might systematically sample every third topic for use as the basis for a test question.

This approach assumes that the various sections of the text are reasonably equal in importance. If such is not the case, or if no single text formed the basis for the course, the instructor may wish to create his own list of topics.

6. Decide what level and distribution of difficulties is appropriate for the questions included in the test.

There are two ways in which this problem can be approached. One is to include in the test only those problems or questions which any student who has studied successfully should be able to answer. If this is done most of the students should be expected to answer most of the questions correctly. To put it somewhat differently so many correct answers will be given that many of the questions will not be very effective in discriminating among various levels of achievement--best, good, average, weak and poor.

The other approach is to choose the questions likely to contribute most information as to relative levels of achievement among the students tested. This requires preference for somewhat harder questions, so that approximately half the students would be expected to do well on them and the other half poorly. This second approach will generally yield more reliable scores for the same amount of testing time. But it may be more disturbing to the students who take it, and will not seem to reflect any minimum standards of competence for a passing score.

Some instructors believe that a good test includes some difficult questions to "test" the better students, and some easy questions for the poorer students. This belief would be justified if each new unit of study in a course, or each new idea required the mastery of all preceeding units and ideas presented in the course. In such a course students would differ in how far they had successfully progressed through it, rather than in how many separate ideas they had grasped.

No course illustrates perfect sequence of units and ideas. A student who has missed some of the early ideas, or done poorly in some of the early units of study, will usually be handicapped in later study, but the sequence of development is seldom so rigidly fixed that his early lapses or deficiencies prevent later progress. Foreign language courses, and courses in some branches of mathematics and engineering show more sequential dependence than other courses, but even in them the dependence is far from absolute.

For most courses of study the difference between good and poor students is less in how far they have gone than in how many things they have learned to know and to do. In such courses, and unless the students are extremely variable and the test extremely reliable, there is no need to vary the difficulty of the questions on purpose. Theoretical analyses and experimental studies demonstrate quite convincingly that in most situations tests whose questions are neither very difficult or very easy are best.

7. Decide whether, and if so how, to determine the passing score on the test.

The traditional student attitude toward tests is that the most important outcome is whether one passed or failed the test. Many instructors, retaining the student's point of view, share this attitude. But it is not a particularly rational or useful attitude. Unless a particular test is the sole basis for the pass or fail decision, which it seldom should be precisely defining a passing score on it may be more bother and cause more trouble than it is worth.

The operational significance of academic failure is that the student receives no credit for the course, and sometimes must repeat it. This is a serious, complex decision which should be made deliberately and after full consideration of all relevant factors. Usually several persons other than the teacher--the administrator, the student's advisor, even the student himself--should be consulted before the decision is finally made. It should seldom be a purely clerical, automatic, impersonal decision. Students have a right to know in advance the basis on which the instructor will decide whether to pass or fail a student, and the proportion of a group that is likely to fail. Students also have a right to know how their scores on a test affect their own chances of passing. If approximately 10% are expected to fail, and if a student's score places him in the lowest 20%, he should know that he is in trouble. But it is not very helpful to tell those in the lowest 10% that they have failed the test and the others that they have passed.

Educational achievement is a continuous variable. No great gulf is fixed between those who pass and those who fail until the final decision is made. Any cutting score is at least partly arbitrary, and some failures, as well as some passes can properly be attributed to chance, to bad or good luck as the case may be. There is no way of avoiding the arbitrariness or the influence of chance in the ultimate decision, but there is no point in multiplying the problem by making pass or fail decisions on each test.

Some instructors believe that what one must know to pass a course is fixed by the course content, and by subsequent demands on the student. They hold that decisions to pass or fail can and should be made in terms of impersonal, absolute standards set by the subject matter. I seldom find these beliefs acceptable. Course content is usually selected on the basis of subjective decisions, often by individual instructors. As such it hardly possesses the characteristics of an absolute standard of achievement. Nor is it ordinarily possible for the constructor of an objective test to gauge the difficulty of his items precisely enough to define a fixed standard of achievement with respect to that content. Those who use essay tests apply a flexible subjective scale of evaluation which permits them to say, "A score of 75% on this test is passing," without passing too many or too few. But with an objective test, the die is cast when the test is made and the test constructor's lack of precisely applicable absolute standards of achievement is all too apparent when the test is scored. The essay test grader has the same limitations, but he finds it easier to conceal them.

All this suggests that, when a passing score on a test must be determined, a number of factors should be considered. Probably the relative standing of the student in the group should be the most influential of these. The proportion of failures in a class ordinarily should be fairly constant from class to class. It is absurd to decree that, in any class, exactly 7% of the students should fail. But it is even more absurd to tolerate measurement practices which allow the proportion of failures, in comparable groups, to fluctuate from 0% to 50%. Theoretically absolute standards have generally proved quite unreliable. Relative standards are not ideal, but they do make an important contribution to stability and fairness in setting the passing score, in the rare instances where failure must be determined from a single test.

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No doubt the constructor of a classroom test will face other decisions in particular situations. Even if all of these could be anticipated it would be impossible to deal with them all in a brief introductory discussion such as this. It may, however, be appropriate to conclude by reemphasizing the importance, as well as the difficulty, of one crucial area of decisions, the decisions on what to test. The most serious weaknesses of classroom tests are due to the neglect of these decisions, or to the acceptance of conventional wrong answers respecting them.

Many teachers admit that their tests do not adequately reflect the really important outcomes of their courses. Some are convinced that no test, and certainly no objective test, could adequately measure student achievement of these objectives. I am skeptical of this view. I am persuaded that all defensible outcomes of public education are inherently objective, and hence testable. If we would only be a little more objective in our statements of objectives, a little less imaginative and fondly hopeful, we could guide our decisions better on what to test. The problem, I think, is solvable. Let us work on it.

EXHIBIT A

MULTIPLE CHOICE ITEMS INTENDED TO TEST VARIOUS ASPECTS OF ACHIEVEMENT

Vocabulary

1. The term "fringe benefits" has been used frequently in recent years in connection with labor contracts. What does the term mean?

(1) Incentive payments for above-average output.
(2) Rights of employees to draw overtime pay at higher rates.
(3) Rights of employers to share in the profits from inventions of their employees.
*(4) Such considerations as paid vacations, retirement plans, and health.

2. What is the technical definition of the term production?

(1) Any natural process producing food or other raw materials.
*(2) The creation of economic values.
(3) The manufacture of finished products.
(4) The operation of a profit-making enterprise.

Knowledge of Fact

3. What principle is utilized in radar?

(1) Faint electronic radiations of far-off objects can be detected by super-sensitive receivers.
*(2) High frequency radio waves are reflected by distant objects.
(3) All objects emit infra-red rays, even in darkness.
(4) High frequency radio waves are not transmitted alike by all substances.

4. What change occurs in the composition of the air in a lighted air-tight room in which the only living things are growing green plants?

(1) Carbon dioxide increases and oxygen decreases.
*(2) Carbon dioxide decreases and oxygen increases.
(3) Both carbon dioxide and oxygen increase.
(4) Both carbon dioxide and oxygen decrease.

Explanation

5. If a piece of lead suspended from one arm of a beam balance is balanced with a piece of wood suspended from the other arm, why is the balance lost if the system is placed in a vacuum?

(1) The mass of the wood exceeds the mass of the lead.
(2) The air exerts a greater bouyant force on the lead than on the wood.
(3) The attraction of gravity is greater for the lead than for the wood when both are in a vacuum.
*(4) The wood displaces more air than the lead.

6. Should merchants and middlemen be classified as producers or non-producers? Why?

(1) As non-producers, because they make their living off producers and consumers.
(2) As producers, because they are regulators and determiners of price.
*(3) As producers, because they aid in the distribution of goods and bring producer and consumer together.
(4) As producers, because they assist in the circulation of money.

Calculation

7. If the radius of the earth were increased by three feet, its circumference at the equator would be increased by about how much?

*(a) 9 feet (c) 18 feet
(b) 12 feet (d) 28 feet

8. What is the standard deviation of this set of five measures--1, 2, 3, 4, 5?

(a) 1 (d) $\sqrt{10}$
(b) $\sqrt{2}$ (e) none of these
(c) 9

Application

9. Which of these practices would probably contribute LEAST to reliable grades from essay examinations?

*(1) Weighting the items so that the student receives more credit for answering correctly more difficult items.
(2) Advance preparation by the rater of a correct answer to each question.
(3) Correction of one question at a time through all papers.
(4) Concealment of students' names from the rater.

10. "None of these" is an appropriate response for a multiple choice test item in cases where:

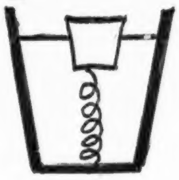
(1) The number of possible responses is limited to two or three.
*(2) The responses provide absolutely correct or incorrect answers.
(3) A large variety of possible responses might be given.
(4) Guessing is apt to be a serious problem.

Prediction

11. What would happen if the terminals of an ordinary household light bulb were connected to the terminals of an automobile storage battery?

(1) The bulb would light to its natural brilliance.
*(2) The bulb would not glow though some current would flow through it.
(3) The bulb would explode.
(4) The battery would go dead.

12. In a beaker almost full of water a cork is nearly submerged by the pull of a spring. If the beaker is allowed to fall free, what will happen to the cork during the period of free fall?



(1) It will stay nearly submerged.
*(2) It will submerge completely.
(3) It will float higher in the water.
(4) It will alternately submerge and rise out of the water.

BASIC CONSIDERATIONS IN GRADING THE ACHIEVEMENT OF COLLEGE STUDENTS

I. The nature of the problem

The problem of grading student achievement has long been a troublesome one at all levels of education. We have shifted from percent grades to letter grades. We have experimented with simplified pass-or-fail grades, verbal reports, and a variety of other schemes. And still our problems remain. Hardly a month goes by without the appearance in some educational journal of an article criticizing current practices, or suggesting some new approach.

Recently there has been evidence that college faculties throughout the country are becoming more aware of the problem, and more anxious to find some reasonable solution to it. The chief source of concern is that the grading practices of different instructors and departments differ greatly, and that all of them tend to give too many high grades. Wide publicity was given to the dismay of the faculty of Yale College when they discovered the names of nearly half their students on the Dean's List for academic honors. Recent faculty bulletins on grading published by the University of North Carolina, by the State University of Iowa, and by the University of Florida reflect the same concern over the lack of uniform grading standards, and the same desire for improvement.

There are several issues that arise persistantly in most discussions of the problem of grading.

1. Are grades necessary?
2. Should each instructor conform to institutional policies in grading?
3. Is "grading on the curve" justified?
4. Is it justifiable to give more high grades in advanced courses or in courses which enroll especially capable students?
5. Should grades be regarded as measures or evaluations?
6. Should grades reflect a student's attitude, effort, and amount of improvement, or simply the level of achievement he has reached?
7. Is the present general system of grading, making use of five-letter grades, the best that can be devised?

Not all of these seven issues have been equally prominent in previous discussions, nor equally controversial, but they are all crucial. We will not attempt to give unequivocal answers to each of the questions, and to support our answers with as much logic and evidence as possible. There will not be unanimous agreement that the answers we propose are correct or completely satisfactory. But I hope we can achieve a much greater consensus than has been generally evident in discussions of grading, and I know we will all benefit by thinking clearly and critically about these issues.

1. Are grades necessary?

Grades are necessary. They are necessary at all levels of education. Certainly they are indispensible at the college level. Few college professors are likely to disagree seriously with this point of view. But there have been enough suggestions by some educationists that grades are unnecessary relics of the dark ages of education, to justify some attention to this issue. For if college professors regard grades as either trivial or harmful they are not likely to take enough care to do a good job of grading.

The uses made of marks are numerous and crucial. They are used to report a student's educational status to him, to his parents, to his future teachers, and to his prospective employers. They provide an important basis for crucial decisions concerning his educational plans and his occupational career. College education is expensive, and there are not enough opportunities for college education to go around. If we are to make the best possible use of our educational resources, and of our student talent, it is essential that each student's educational progress be watched carefully, and reported as accurately as possible. Grade reports serve somewhat the same function in college education that financial statements serve in business. In either case, if the reports are inaccurate or unavailable, the venture is likely to be inefficient, and ultimately to fail.

Grades also provide an important means for stimulating, directing, and rewarding the educational efforts of students. Some educational theorists have attacked this use of grades on the ground that it provides extrinsic, artificial, and hence undesirable stimuli and rewards. Indeed grades are extrinsic, but so is the professor's monthly salary check. We are grateful for the intrinsic rewards associated with learning and with teaching, but we are even more grateful that these are not the only rewards. Most of us have had enough experience, and know enough about human behavior, to understand that few formal, efficient educational enterprises can be conducted successfully on the basis of intrinsic rewards alone.

To serve effectively the purpose of stimulating, directing and rewarding student efforts to learn, grades must be valid and reliable. The highest grades must go to those students who have achieved to the highest degree the objectives of instruction in a course. Grade assignment must be based on sufficient evidence so that they report the degree of achievement as precisely as possible. If grades are assigned on the basis of trivial, incidental, or irrelevant achievements, or if they are assigned carelessly, their long run effects on the educational efforts of students cannot be good.

Some students and some teachers minimize the importance of grades by arguing that what a person learns is more important than the grade he gets. This argument begs the question by assuming that there generally is not a high relationship between the amount of useful learning and the grade received. Others have made the same point by asserting that grades are not "ends-in themselves," and by criticizing the use of examinations "merely for the purpose of assigning a grade." Of course the grade a student receives is not in itself an important educational outcome. But then neither is the degree toward which the student is working, nor the academic rank or scholarly reputation of the professors who teach him. But all of these symbols can be and should be valid indications of the attainment of important educational goals. It is highly desirable, and not particularly difficult, to make the goal of maximum educational achievement identical with the goal of highest possible grades. If the goals are not identical, it is the fault of those who teach the courses and who assign the grades. From the point of view of students, parents, teachers, and employers there is nothing "mere" about college grades.

Grades are necessary. If they are inaccurate, invalid, or meaningless, the remedy lies not in de-emphasizing grades, but in assigning them more carefully so that they do truly report the extent of important achievements. Instead of seeking to minimize their importance by specious arguments, or seeking in vain to find some painless substitutes, we should devote our attention to improving their validity and precision, and to preventing misinterpretations of grades by students, faculty and others who use them.

2. Should each instructor conform to institutional policies in grading?

He should, or grades will lose their meaning, and the grading system will fail to perform its essential functions. A marking system is essentially a system of communication. It involves the use of a set of specialized symbols. Only to the degree that these symbols have the same meaning for all who use them is it possible to communicate meaningfully precisely.

The meaning of a grade should not depend on the teacher who issued it, the course to which it pertains, the student who received it, of the college in which it was earned. This means that the marking practices of an instructor, of a department, or indeed of a college, are matters of legitimate concern to other instructors, other departments, and other colleges. It means that a general system of grading ought to be adopted by the faculty and the administration of a college. It means that the meaning of each grade should be clearly defined. General adherence to this system and to these meanings ought to be required of all staff members. Such a requirement would in no way infringe the right of each instructor to determine which grade to give to a particular student. But it would deprive him of the right (which some instructors have claimed) to set his own standards, or to invent his own meanings for each of the grades issued.

Most college faculties have formally adopted some grading system, but there seems to be considerable difficulty in getting the instructors to follow it. A number of studies have indicated that different teachers, different departments, and different colleges vary widely in the distribution of the marks they issue, even when they are supposedly employing the same system. We find instructors in one department issuing 63% A's or B's, whereas those in another issue only 26% A's or B's. Course X in one department granted 66% A's and B's, whereas Course Y granted only 28%. Each of these courses, incidentally, enrolled more than 50 students.

Lack of stability in the assignment of grades from year to year is also apparent. Specifically, there appear to be long run tendencies in many institutions to increase the proportion of high grades issued and to decrease the proportion of low grades. For example, during the years 1936 to 1939 one large institution issued 33% A and B grades. From 1951 to 1954 the corresponding proportion of A's and B's had increased to 44%. In the same two periods the proportion of D's and F's dropped from 30% to 18%.

One reason for these variations may be that certain instructors regard grading as a purely private matter. They fail to distinguish between their unquestioned right to determine which grade an individual student shall receive, and their unrecognized obligation to make their grades meaningful by following college-wide grading policies.

An explanation for the tendency of instructors to issue more high grades and less low grades is the human tendency to follow the path of least resistance. An instructor seldom has to explain or justify a high grade, or to calm the anger of the student who received it. Or the instructor may feel that the favorable reputation of his courses on campus depends on his generosity with high grades. Then too, many of the best instructors like their students so much as persons that they find it very difficult to disappoint any of them with a low mark, particularly if they seem to have been trying to learn.

These temptations to depart from standard grading practices are understandable, but they are not acceptable as justifications. Some institutions help their staff members to withstand these temptations by systematically publishing grade distributions by courses, by departments, and by colleges each semester. Others require instructors to submit, along with their grade lists, summaries of the distribution of grades they have issued. It was even proposed informally in one institution that instructors who persist in reporting grades out of line with established policies should have their grades corrected downward or upward one level to bring the average of all grades issued closer in line with the intended average.

There are, indeed, some situations which justify departure from the recommended distribution of grades. Some of these situations will be considered later in the discussion of other issues. The point here is that justifiable exceptions are much rarer than is commonly believed.

Perhaps the most fundamental reason for lack of uniformity and stability in grading practices is lack of a clearly stated, generally accepted, practically effective definition of what the various grades should mean. To reach such a definition, it is necessary to consider the third issue concerning grading practices.

3. Is "grading on the curve" justified?

Grading on the curve, or more precisely, grading on the basis of observed differences in student achievement, is justified. In fact it is the only logically defensible and practically effective basis for grading. This issue has been discussed with greater vehemence than any other issue related to grading. It is seldom remembered, or pointed out, that the shift most institutions made years ago from numerical percentages to letter grades carried with it implicit recognition of the fact that grades on educational achievement are intrinsically and inescapably relative.

The alternative to grading on the curve is grading on the basis of absolute standards. But absolute standards are impossible to define in objective terms for most areas of achievement. The studies of Starch and Elliott clearly show the fallability of so-called "absolute" judgments of quality in essay examination papers. Identical copies of an English examination paper were given to 142 English teachers, with instructions to score it on the basis of 100% for perfection. Since each teacher looked at only one paper, no relative basis for judgment was available. The scores assigned by the teachers to the same paper ranged all the way from a high of 98% to a low of 50%. Similar results were obtained with an examination paper in geometry, and in history. Apparently, "absolute" judgments are actually far from being accurate judgments.

It is sometimes asserted that these standards are inherent in the subject matter itself. But no one ever learns all there is to know about a subject, nor is it possible to ascertain reliably by any known operations what proportion of the theoretical sum total of knowledge in a field any student possesses. It is equally impossible to set any rational minimum standard for passing, in terms of subject matter alone. Educational achievement does not come in discrete chunks which are easy to count, and which are learned on an all-or-none basis.

A grade of 90% used to be thought to mean that the student who received it had learned 90% of what he was expected to learn in a given course. But it takes very little analysis to discover how little meaning there is in such a statement. In what units do we measure "amount of knowledge"? On what basis can an instructor say how much should be learned in a given course? By what operations can one measure the total to be learned, and the part the student did learn?

Sometimes those who defend so called absolute standards argue that the experienced teacher knows what these standards are, and that the inexperienced teacher can quickly learn them if he will only try. But this is obviously just a roundabout way of saying that the standards are derived from the observed performances of the students themselves, which means that they are relative and are not absolute measures of subject matter achievement at all. In spite of the vehement arguments in favor of absolute, teacher-determined, grading standards, no one has ever described in concrete, operational terms exactly how such standards could be defined and applied.

Before considering objections which have been raised to grading on the curve it may be useful to distinguish two somewhat different processes to which the term is applied. One method for grading on the curve is to determine from the ideal normal curve what proportion of the grades should fall at each fifth of five levels, and to follow these proportions as closely as possible in assigning grades to any class. The best 7% get A's, the next best 23% get B's and so on. The other, better, process is to define the limits of the various grade intervals in terms of the mean and standard deviation of the distribution of achievement. Those whose scores are more than 1.5 standard deviations above the mean get A's, those between .5 and 1.5 standard deviations above the mean get B's, and so on. This second process does not guarantee in advance that 7% of the students must get A's, and 7% must fail. If the distribution of achievement is skewed, as it may be, or irregular, as it often is, these characteristics will be reflected in the proportion of each grade assigned. Perhaps confusion would be avoided if this second process of grading on the curve were referred to as "relative grading."

One criticism of relative grading is that it permits the students rather than the teachers to set the standards. This is true. There is the further implication that student set standards are likely to be low--lower at least than those most teachers would set. But this appears not to be true. For when the teachers depart from the proportions of grades recommended by a relative grading system, they seem to do it by giving too many high grades and too few low grades.

Another way of stating essentially the same criticism is to claim that relative grading encourages a general slow-down of student effort. The argument is that under a relative system of grading the members of a class can earn just as good grades if they take it easy as if they put forth maximum effort. There is nothing wrong with the logic of this argument, but there is a great deal wrong with its application to practical classroom situations. How can any student who agrees to this general slow-down be sure that some mediocre student may not cheat a little on the slow-down and wind up receiving the A which the outstanding student thought he would get? Many instructors have expressed fear that relative grading would lead to such a slow-down. A few students have reported participating in classes where it actually happened. But there is no unbiased, objective evidence that it ever did happen. And if it did, the blame would seem to lie more with the barren, trivial nature of the course, or with generally poor student motivation, than with relative grading. For ordinarily the competition implicit in relative grading calls forth the maximum effort from human beings. At least we claim that it is competition (relative measurement) which keeps free-enterprise economy in high gear.

In all areas of human activity awards go to individuals who are outstanding in relative, not absolute terms. There are no absolute standards for speed in running the mile, or for distance in throwing the javelin. The winner in any race is determined on a relative basis. Have you ever heard of runners on a starting line agreeing to take it easy simply because there is no absolute standard of speed they have to meet? From the point of the individual runner in the 100 yard dash, as well as from that of the individual student majoring in history or chemistry, the best way to achieve outstanding success is to put forth maximum individual effort. And this is even more likely to be true when success is judged in relative terms than it would be if success were measured in absolute terms.

A more serious criticism of relative grading is that it fails to take account in differences from group to group in the general level of achievement or in the variability of achievement within the group. This criticism applies with particular force when the groups being graded are relatively small. Experienced teachers know that it is unreasonable to assume each small group will be exactly like every other small group in general level of achievement, or in variability of achievements within the group. But it is equally unreasonable to assign more than the normal proportion of high grades year after year just because the classes are small. In a succession of small classes the accumulated proportion of grades in each category should approximate those called for by the normal curve. The answer to the small class criticism of relative grading is to be found, therefore, in basing the grades on the largest possible sample of student achievements. This is what most teachers who use relative grading practices actually do. They accumulate records and experience from year to year. And, parenthetically, this is what most teachers are really arguing for when they talk about the need for "absolute standards."

But there is another facet to the question of relative grading. It is well known that some courses tend to enroll better students than others over a long period of time. This raises the next issue.

4. Is it justifiable to give more high grades in advanced courses, in specialized courses, or in courses which enroll particularly capable students?

No simple answer can be given to this complex question. If course grades are interpreted as multiple independent measurements of a student's general level of ability, then more able students in more advanced courses do deserve higher marks than less able students in more elementary courses. But if the courses enrolling students at different levels of ability are clearly identified, and if the grades are interpreted as indications of how well the student succeeded in tasks considered appropriate for his level of educational development, then differential grading standards are unnecessary and undesirable.

This latter point of view is not widely accepted among college faculties. On the contrary, there is ample evidence that professors tend to retain and defend differential grading standards. They are usually willing to agree that courses which enroll the more capable students are entitled to give more high grades. If they accept a grade as low as D for credit in undergraduate courses, they insist that the minimum grade carrying graduate credit shall be a C or a B.

Now the fundamental reasons why these practices are questionable is that they represent attempts to measure in absolute terms something which can be measured most reliably and most conveniently in relative terms. If an instructor who believes in absolute standards of grading were to be entirely consistent, he would need to argue that students in their first semester of college German could not possibly earn grades higher than D while those in their eighth semester could not possibly earn grades lower than B. The fact that they are willing to give both A's and F's in introductory as well as in advanced courses indicates that, in some situations at least, they are willing to accept grades as relative measures of achievement.

But there are other reasons why grading practices based on the assumption of absolute grade standards are undesirable. Superior students who never know failure, or need never extend themselves to achieve high marks, are poorly prepared for the situations they will face in life. Because of their outstanding abilities they will tend, year by year, to move into more challenging and more demanding occupations. The rewards will be greater, but the competition will be keener also, and the likelihood of failure will be greater. The pitching sensation of a minor league team may have difficulty getting the side out when he is sent up to the majors. It is unrealistic, and psychologically unwise, to run our educational institutions as if the more capable students are entitled to high grades in every course in which they are enrolled.

A similar argument can be made for relative grading in those classes which enroll primarily the less capable students. Many colleges differentiate their courses in freshmen English in response to the wide differences in the needs and abilities of students' enrolling in those courses. Whether the most elementary of these courses, enrolling the least capable students, should carry college credit is a question for the faculty to decide. But this has little or nothing to do with the grading practices to be followed in such courses. So long as the courses are different, designed to be appropriate for students at different levels of development, and so long as this difference is clearly reflected in the course title, it is appropriate to use the entire range of relative grades in each of the courses, elementary, intermediate, or advanced.

Recognition and acceptance of this principle would eliminate some of the headaches of instructors required to teach the most elementary sections, and would probably lead to a better general level of achievement on the part of the students in those sections. It is neither necessary nor wise to arrange our educational institutions so that some students are predestined to do below average work, and receive below average grades, in every course they undertake to follow.

The basic principle of relative grading is that a student's achievement should be graded by comparing it with the achievement of the student's peers. But who, for example, are the peers of a talented girl studying vocal music? Are they all the girls of her own age in the country, in school and out? Or are they all the girls attending the college she attends? Or are they only those girls specializing in vocal music at the same stage in their training as she is? It seems quite clear that the best way to give grades clearly defined operational meaning is to grade a student's performance relative to the performance of other students taking the same course. It is neither feasible or reasonable to compare the vocal performance of a girl who is trying to learn to sing exceptionally well with the vocal performance of other girls who are not trying to learn to sing at all. Hence it seems somewhat unreasonable to insist that students with special talents should never be given average grades.

If we reject the notion that grades are or can be absolute measures of achievement, and if we learn always to ask what they are relative to--what course work and what group of students--we should find fewer problems in grading, and should give more meaningful and reliable grades.

5. Should grades be regarded as measurements or as evaluations?

Grades should be regarded as quantitative measures of achievement rather than as qualitative evaluations of achievement. The two terms, measurement and evaluation, have been used so often as near synonyms that this attempt to differentiate them may seem trivial. But an important distinction can be made, and ought to be made, not only in the interest of more precise use of terms, but also, and far more important, in the interest of more effective grading practices. Much of the difficulty and dissatisfaction with marking systems has arisen from failure to distinguish between measurement and evaluation, and from failure to restrict grading systems to reports of measured achievement. In the minds of most students, and probably in the minds of most instructors, grades are regarded as an indistinct blend of measurements and evaluations.

As we shall use the term, a measurement in education is a quantitative description of how much a student has achieved in relation to the achievement of his peers. A measurement is objective, impersonal, and can be quite precisely defined in operational terms. An evaluation, on the other hand, is a qualitative judgment of how good or how satisfactory the student's performance has been. Evaluations tend to be subjective, quite highly personal, and difficult to define precisely. Evaluations are often based in part on measurements of achievement, but they are also based on many other kinds of evidence. Measurement can describe how much of this ability or that characteristic an individual possesses. But to tell how well educated he is, or how well prepared for a particular job we must make an evaluation.

There are several reasons why a grading system should be treated as a system for reporting measurements of achievement rather than as a system for reporting evaluations. In the first place, evaluations are too complex, involving too many variables and too many considerations which are unique to a particular student, to be reported adequately in any standardized grading system. Judgments of how good a student's educational achievement has been depend not only on how much he has achieved, but also on his opportunity for achievement, the effort he has put forth, and the need which this achievement is likely to serve in his educational and vocational future. It is not easy to make grades valid as measures of achievement, but it is next to impossible to make them valid as evaluations.

In the second place, because of the many poorly defined and highly individual factors which must be considered in making an evaluation, few teachers have any adequate basis for making fair evaluations. What teacher is well enough informed about the personal life, and the personal problems, of each of his students to judge accurately each student's opportunity to learn, and the real effort he has made to learn? A teacher can help a student make an honest evaluation of his achievements, but the teacher cannot do the whole job alone. And the teacher should not, even if he could. Imposed evaluations are not only less accurate than self evaluations. They are less effective also. This is the third reason for restricting grades to measurements of achievement.

If students and teachers regard marks as objective measurements of achievement rather than as subjective evaluations, two desirable things will happen. There is greater likelihood that the teachers will assign fair and accurate marks. There is less likelihood that students will suffer serious emotional reactions, and that the relations between student and teacher will be damaged.

Consider this analogy. If the scale shows that you weigh 210 pounds it is reporting a measurement. The fact may be unpleasant, but there is nothing personal about it, and no cause for anger at the scale. But if a tactless relative suggests that you are getting too fat he is making an evaluation. It is a personal affront, and you would be superhuman if you did not resent it. The fact that you have been thinking the same thing yourself does not help a bit. In the same way, the interpretation of marks as evaluations rather than as measurements has been responsible for much of the tension and unpleasantness associated with their use.

Finally, there is little need or justification for making a formal report and a permanent record of evaluations. It is far less important for a future teacher or employer to know that Henry did as well as could be expected of him, or that he failed to live up to expectations, than to know that he is outstanding in his ability to handle language, or mediocre in his mathematical ability. Evaluations are instrumental to particular decisions, and once these decisions have been made there is little to be gained by basking in a favorable evaluation, or in agonizing over an unfavorable one. If one would be successful, and maintain emotional stability, it is important that he learn not to cherish too long the evaluations that others have made of him or that he has made of himself. Measurable achievements, on the other hand, represent the more permanent foundations on which future education and success depend. The more accurately they are reported, and the more completely they are recorded, the more soundly a student and his advisors can judge which choices he should make.

A teacher is well advised to regard the marks he assigns in a course as objective, impersonal measures of achievement rather than subjective, personal evaluations, and to train his students to accept tham on this basis.

6. Should grades reflect the student's attitude, effort, and amount of improvement, or simply the level of his achievement?

What has just been said provides a reasonable clue to our answer to this question. Grades should not aim to report, nor be greatly influenced by the student's attitude, his effort, or the amount of improvement he has made. They should simply report the level of achievement he has reached.

One of the important requirements of a good grading system is that the grades be fair. This means that they ought to indicate as accurately as possible the extent to which the student has achieved the objectives of instruction in the particular course of study. If improving the student's attitude towards something, or his willingness to put forth effort for educational achievement, is one of the specific objectives of the course, and if, further, the instructor has planned specific educational procedures in the course to attain this goal, then it is quite appropriate to consider these things in assigning grades. But usually this is not the case. When it is not, attitude, effort and improvement should be excluded from consideration in determining the grade to be assigned. Too often a student's grade has been influenced by the pleasantness of his manner, his willingness to participate in class discussions, his skill in expressing ideas orally or in writing, or his success in polishing the apple. These things should not be allowed to influence the grade he receives.

Some instructors, seeking fairness in their grades, have attempted to base them on the amount of improvement a student makes rather than in the level of achievement he reaches. Such measures of improvement, even if they could be made accurately, would not be as useful to report as measures of the level of achievement reached. One can always calculate measures of growth from measures of status, but the reverse of the process is impossible. And measures of improvement can seldom be made with satisfactory accuracy. Measures of status are never perfectly reliable, and the difference between two unreliable measures is far less reliable than either of the measures themselves. Many teachers, particularly in the public schools, pay lip service to the measurement of growth. Few actually attempt to measure growth precisely. If they did, and if they seriously investigated the reliability of their measures of growth, they probably would find the process much less attractive.

7. Is the present five-letter grading system the best that can be devised?

It probably is not. A more satisfactory alternative system has been devised, and is already being used in some areas, particularly in the military services.

The five-letter grading system represented an important improvement over the old percentage grading system. It was an honestly relative system of measuring achievement. It avoided the unwarranted assumption that achievement could be measured in absolute terms. But the five-letter system does not provide enough symbols to permit accurate reporting of all levels of achievement which the teacher can observe. Persistent efforts are made by teachers to refine the system by adding plus and minus signs to the letter grades they report. Such cumbersome additions are highly unpopular with registrars and others who must deal with grades, however.

There is another limitation of the five-letter grading system which ought to be corrected. It was never clearly identified as a system of measurement rather than as a system of evaluation. Persistent use of letter grades to serve both purposes has probably spoiled them for exclusive use as measures of achievement.

During World War II the armed forces began to use a nine category system involving single digit numerals from 1 to 9. This was referred to as the standard nine, or stanine scale. Few, if any, attempts have been made thus far to introduce this system in our colleges and universities. It does have two important advantages. It provides a more refined scale of measurement. It carries clear connotations of measurement rather than of evaluations. College faculties will be well advised to give careful consideration to this system when they contemplate any change in their general practices.

Concluding statement.

We have considered some of the basic issues in college grading practices and some possible solutions to them. Grades are necessary. A uniform grading system ought to be adopted and adhered to. Relative grading is necessary because measurements of human achievement are inherently relative. The full range of available grades should be used in all courses, regardless of their degree of advancement, their specialization, or their enrollment of particularly capable students. Grades should be treated as measurements not as evaluations. Grades should reflect the level of a student's achievement, not his attitude, effort, or amount of improvement. And finally, a numerical stanine system would be a definite improvement over the present five-letter grading system.

A grading system is essentially a system of communication. As such, its effectiveness depends on how clearly those who use it and are concerned with it understand the meaning of its symbols. The ultimate goal of the suggestions offered in this paper is to promote a grading system which can be clearly defined, generally understood, and which will contribute to effective education.

HOW TO JUDGE THE QUALITY OF AN EXAMINATION

What makes a classroom test a good test? This question concerns both students and instructors whenever a test is given. Too often it goes unanswered or is badly answered, for lack of sound standards of quality and convenient techniques of applying them. Some of the important factors which need to be considered in judging the quality of a test are indicated by the statements below. A good examination:

1. Is fair to the course, in view of the things the course is supposed to teach.
2. Is fair to the students, in view of the instruction given them.
3. Makes efficient use of the instructor's limited time for preparation and grading, and of the student's limited time in the examination period.
4. Emphasizes important, long-run achievements more than incidental, quickly-forgotten information.
5. Is administered under conditions which give each student a good and an equal chance to demonstrate his achievements.
6. Is composed of questions which are individually effective in distinguishing between good and poor students.
7. The questions are of appropriate difficulty, neither too hard nor too easy.
8. Distinguishes clearly between students at different levels of ability.
9. Yields reasonably reliable scores which would agree closely with those from another equivalent test.
10. Is appropriate in length for the time available--long enough to give reliable scores but short enough so most students have time to attempt all items.

Answers to the first five statements depend largely on the knowledge and judgment of the instructor which, however, can be balanced, supported or corrected to some degree by the opinions of his students and colleagues. Answers to the remaining five can be obtained by test analysis.

Such an analysis is applied most easily to objective tests. It is, however, applicable in part to problem type tests such as those used in engineering. The only restriction is that individual questions must be separately scored.

1. Fairness to the course.

In general, any course is expected to make some permanent changes in the students who take it--to leave them with new knowledge and understanding, improved and extended abilities, new attitudes, ideal and interests. But often these long-range goals are neglected when tests are constructed. Instead of being evaluated on the basis of ultimate objectives, the student is often judged on the basis of his memory of what went on from day to day in the class, or what he read in preparation.

Where several instructors are concerned with teaching the same course, it is quite common for all to share the responsibility for test construction. This practice ought to be extended to single-section courses. Instructors in the same area ought to exchange examinations for review and constructive criticism. While it is true that the best instructors give courses which are unique products of their own special abilities, the important achievements they teach and call for in their tests ought to be things that most of their colleagues would also accept as true and important. No instructor should feel obligated to make all the changes in his test suggested by his colleagues. The ultimate responsibility for its goodness or badness is his. But independent reviews of a test by competent colleagues cost little additional time and often yield large returns in improved quality.

2. Fairness to students.

A test is fair to students if it emphasizes the knowledge, understanding and abilities which were emphasized in the actual teaching of the course. Occasionally a test includes questions which ought to be covered in the course but which were somehow omitted in the instruction of the group being tested. Again, an instructor may evaluate student achievement in a course on the basis of skills--such as ability to spell correctly--which the instructor regards as important but which he made no attempt to teach in the course. Such tests are not entirely fair.

Instructors are in the best position to judge the fairness of a test to their students. A student's opinion on this matter is often biased by his success or lack of success with the test. Probably no effective test has ever been given that was regarded as perfectly fair by all persons taking it. On the other hand, student comments on a test's fairness are often worth securing and considering. If it does nothing more, the request for comments will show the instructor's concern for fairness. And often it can do much more. A student may call attention to ambiguity in a question, to the presence of questions dealing with matters not covered in class, or to omission of questions on matters which were stressed. There are few classroom tests so good that they cannot be improved on the basis of student comments and suggestions.

3. Efficient use of time.

If a large group is to be tested, or if the same test can be given repeatedly to successive groups, the most efficient use of an instructor's time may call for him to use objective, machine-scorable questions. Such questions are time-consuming to prepare, and many more are required, than in the case of problem or essay type questions. But once prepared they can be scored most efficiently and can be used repeatedly. But if a unique test must be prepared for each separate small group, the advantage in efficiency is on the side of the problem or essay type.

In general, objective type questions make the more efficient use of the student's time than do essay questions. A student can read and react to choice type questions much faster than he can write discussions in answer to essay questions. Hence he will reveal his ideas, or lack of them, at a higher rate per minute on an objective test than on an essay test.

With problem tests, the student spends more time thinking than writing. If provision is made for analytic and partial-credit scoring, not just all-or-none scoring, the problem test can be just as efficient as the objective test in its use of the student's time.

4. Important achievement.

Sometimes a test consists mainly of questions requiring recall of some detail in the process of instruction--"How did the lecturer illustrate Hooke's Law?"--or requiring reproduction of some unique organization of subject matter--"What were the three chief reasons for the failure of the League of Nations?" Such items do not measure important achievements. If, on the other hand, a majority of the questions deal with applications, explanations, and generalizations, if knowledge of terms and isolated facts is not the sole aim of a large proportion of the questions, and if few questions deal with matters of no consequence outside the classroom, the test does emphasize important achievements.

5. Conditions of administration.

Was the test handled efficiently and quietly, with no confusion or disturbance which might interfere with effective performance? Were all examinees on an equal footing so far as prior knowledge of the examination was concerned? Did they have enough prior knowledge to be able to prepare properly for it? Was cheating prevented? Were physical conditions of light, heat, and freedom of movement satisfactory? These questions are best answered by the instructor who gave the test. But here again, if any doubt exists about conditions of administration, student comments can be helpful.

6. Discriminating power of the questions.

The discriminating power of a question is indicated by the difference between good and poor students in proportions of correct response. For sound statistical reasons those students in the top 27% on total test score are taken to be good students, and those in the bottom 27% are taken to be poor students. If the difference in mean score on the question for the good students is higher than that of the poor students by more than one-third of the maximum score on the questions, the question is said to be highly discriminating. The more questions classified as highly discriminating, the better the test.

7. Question difficulty.

In essay or problem tests, the average score is determined largely by the choice of the scorer. He may choose to allow ten points per question but seldom give less than five, thus giving some basis for satisfaction to even the poorest student. Or he may choose a more limited range of scores and actually use all of it. If the score for a question is determined by analysis of the student's answer, giving one point for each essential element in the answer, then a question appropriate in difficulty would show an average score of approximately half of the maximum possible score.

8. Levels of ability.

In order for a test to distinguish clearly between students at different levels of ability it must yield scores of wide variability. This is measured by the standard deviation. The larger it is, under ordinary conditions, the better the test. A standard deviation of one-sixth the range between highest possible score and the expected minimum score is quite satisfactory. For some good tests the standard deviation is more than one-fourth of the available range. For poorer tests it may be less than one-tenth of the available range. If a test is too hard, too easy or composed of too many poorly discriminating items, it will yield scores having a small standard deviation. The size of the standard deviation of a set of test scores is an important factor in their reliability.

9. Test reliability.

The coefficient of reliability represents the estimated correlation between the scores on the test and scores on another equivalent test, composed of different items, but designed to measure the same kind of achievement. It can be calculated from the formula

$$r = \frac{k}{k - 1} \left[1 - \frac{\sigma q^2}{\sigma t^2} \right]$$

where r is the coefficient of reliability, k is the number of questions in the test, $\underline{\sigma q^2}$ is the square of the standard deviation of scores on a single question, $\underline{\Sigma}$ means that these squared standard deviations for all k questions are to be added together, and $\underline{\sigma t^2}$ is the square of the standard deviation of the total scores on the test.

A high reliability coefficient indicates that a student's score was not influenced much by the chance selection of certain items rather than other items for inclusion in the test, or by the student's luck or lack of luck in guessing correct answers. Some good examinations have reliability coefficients of .90 or more. This level is difficult to achieve consistently with homogeneous class groups, and with questions which had not previously been tried out, analyzed and revised. A generally acceptable level of reliability for most course examinations is approximately .70.

Reliability is the most important statistical characteristic of classroom test scores. While validity is more important than reliability, the statistical validity of a classroom test cannot ordinarily be determined. To determine it one needs an external criterion of achievement that is a better measure of true achievement than the test scores themselves. This is seldom available. If the items are highly relevant and the scores are highly reliable, the test will necessarily be highly valid as a measure of the achievement covered.

The reliability of a test depends on how sharply the questions discriminate between good and poor students, how many questions there are, how similar the questions are with respect to the ability measured, and how much the students differ from one another in the ability measured. Thus it is easier to get a high reliability of scores in one subject than in another, and with one group of students than with another. The other two factors of reliability, quality and number of items, are under the instructor's control. If the coefficient is too low it can almost always be raised by improving the questions used, or adding more items, or both.

For essay or problem tests there is another type of reliability which is also important. It is the degree of agreement between independent scorers or even between independent scorings by the same scorer. Essay or problem tests can be reliably scored, but they often are not. Those who use such tests extensively owe it to their students to demonstrate that the scores assigned were not largely the result of chance judgments of the moment, or of the unique opinions of the person scoring them. If an instructor can arrange for competent independent scoring of his essay test papers, a scoring reliability coefficient can be calculated easily by the usual Pearson product-moment formula for a coefficient of correlation.

10. Time limits.

Most tests of achievement at the college level should be work-limit tests rather than time-limit tests. That is, a student's score should depend on how much he can do, not how fast he can do it. Speed may be important in repetitive, clerical-type operations, but it is ordinarily not important in critical or creative thinking or decision making. The fact that good students tend to be quicker than poor students is not a good reason for penalizing the occasional good but slow student. Hence it is recommended that test time limits be generous enough for at least 90% of the students to answer the last question in the test.

Conclusion

Test analysis does not in itself improve a test, but the analysis data makes improvement much easier for the instructor who tries to achieve it. Weak questions identified in the analysis can be discarded or revised. The coverage of the test can be extended and balanced. If the cause of unsatisfactory performance of the test as a whole or of any item is obvious, it can be corrected by the instructor himself. If it is not, outside assistance can be sought from test technicians. The aim of these standardized procedures for test analysis is to make it as convenient as possible for an instructor to evaluate his tests, and to improve them where improvement seems called for.

TEST ANALYSIS REPORT

Test Title Security Transaction k = 100 Job Number 6314

Group Tested Class Students N = 57 Date of Test 2/2/53

Time Limit 2 hrs. Calculator Dorothy Checker Ruth

Characteristic	Ideals	Observed	Rating
I. Relevance			
A. Content details	0%	2%	OK
B. Vocabulary	less than 20%	6%	good
C. Facts	less than 20%	16%	OK
D. Generalizations	more than 10%	11%	OK
E. Understanding	more than 10%	5%	low
F. Applications	more than 10%	60%	good
II. Discrimination			
A. Item			
1. High (.41 and up)	more than 25%	22%	OK
2. Moderate (.21 to .40)	more than 25%	41%	good
3. Low (.01 to .20)	less than 15%	30%	high
4. Zero or Negative	less than 5%	7%	OK
B. Score			
1. Mean	(a) 62.5	64.60	good
2. Standard Deviation	(b) 12.5	9.05	low
3. Reliability	more than .70	.80	good
4. Probable Error		2.71	
III. Speededness			
A. Percent of Complete Papers	more than 90%	100%	good

(a) Midpoint of range between highest possible and expected chance score.

(b) One-sixth of range between highest possible and expected chance score.

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6. Koester, George A. "Using Instructor-Made Tests for Instructional Purposes." Educational Research Bulletin 36: 207-208; September 1957.

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8. Meyer, George. "An Experimental Study of the Old and New Types of Examinations." Journal of Educational Psychology 25: 641-661; December 1934 and 26: 30-40; January 1935.

9. Noll, Victor H. "The Effect of Written Tests upon Achievement in College Classes: An Experiment and a Summary of Evidence." Journal of Educational Research 32: 345-358; January 1939.

10. Ross, Clay C. "An Experiment in Motivation." Journal of Educational Psychology 18: 337-346; May 1927.

11. Skinner, B. F. "The Science of Learning and the Art of Teaching." Harvard Education Review 24: 86-97; Spring 1954.

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WORKSHOP ON TESTING

Philip Weinberg

Bradley University

1. In the morning session, principle factors relating to examinations were presented. We shall endeavor to utilize certain of these as a basis for our activity during the workshop. Major objectives of examinations may be stated as:

    a) The promotion of learning and motivation
    b) The evaluation of course content and instruction
    c) The measure of achievement

    When these are considered we are compelled to note that a primary factor connecting the objectives with their fulfillment is the "QUALITY OF AN EXAMINATION". The details of "PLANNING AN EXAMINATION" for the purposes of "PROMOTING LEARNING" and "GRADING ACHIEVEMENT OF COLLEGE STUDENTS" should provide a basis for discussion during the workshop.

2. Each one is to individually select some course area such as mechanics, thermodynamics, fluid mechanics, circuits, materials or engineering economics and prepare an hour or final examination.

    The examination should be designed to achieve the stated objectives. Hence each person should first list these objectives. (See example) Where possible, it would be of interest to use a variety of examination question types (problem, essay, objective) in a single exam. It is recognized that this is not a customary pattern for engineering examinations however it would be useful for us to work with a composite exam for discussion purposes.

    Moreover for our discussion it is desirable to have several question types designed to measure the achievement on the same objective. The planned examination should be constructed as "work" oriented rather than "time" oriented. The order of arrangement and level of difficulty of the questions should also be considered.

3. The construction of the tests pursuant to the objectives and topics previously presented and the critic thereof will be done in small sub-groups of about seven each. About 90 minutes will be allowed for the construction of the tests and 60 minutes for the discussion of them.

4. Following this, the entire group will rejoin for a general discussion of the points raised during the sub-group sessions.

Course Outline for EE 471
Servomechanisms

		Approximate # of periods
Chap. 1	The Automatic Control Problem	1
Chap. 2	Manipulation of Complex Numbers	1
Chap. 3	Solution of Linear Differential Equations	5
Chap. 4	La Place Transforms	3
Chap. 5	Steady State Operation with sinusoidal Driving Functions	3
Chap. 6	Methods of Determining System Stability	5
Chap. 7	Typical Control Elements and Their Transfer	5
Chap. 8	Types of Servomechanisms and Control Systems	5
Chap. 9	Complex Plane Representation of Feedback Control System	4
Chap. 10.	Design Use of Complex Plane Plots to Improve System Performance	5
Chap. 11	Attenuation Concepts for use in Feedback Control Systems Design	2
Chap. 12	Application of Attenuation--Phase Diagrams to Feedback Control Design Problems	3
	Period Examinations	3
		45

Exam 1	end of Chap. 5
Exam 2	end of Chap. 8
Exam 3	end of Chap. 10
Final Exam	end of Chap. 12

Course Information
Servomechanisms EE 471

Objective: It is the purpose of this course to introduce the fundamental concepts of linear servomechanism theory

General Information:

1. This course is intended for students not majoring in electrical engineering. It is designed to include supplementary information usually not covered in your major field.
2. The text for this course is "Servomechanisms and Regulating System Design Vol. 1" - Chestnut and Mayer.

3. Supplementary References which will be used during the semester are
    - a) Control Engineering - Murphy
    - b) Servomechanism Analysis - Thaler and Brown
4. Instructor: ______________________________
5. Office: __________________________Office Hours______
6. Examinations

   At least two regularly schedules period exams plus the final. Additional short quizzes given throughout semester. Undue memorization is generally not expected for this course of study except for defined fundamental ideas, reference information will be available during examinations.

The objectives of the course leading up to exam #1 are

1. to introduce the concept of feedback in a descriptive sense
2. to review simple complex algebra previously covered in an EE service course
3. to review elementary differential equations, both first and second order
4. To utilize operational methods for the solution of linear differential equations and the consequent application to control systems
5. to review sinusoidal excitation functions applied to linear systems

The objectives of the course leading up to exam #2 are

1. to introduce the concept of stability, Ronth and Nyquist Criteria
2. Study of transfer functions of component parts of system
3. Study of servomechanism systems

The objectives of the course leading up to exam #3 are

1. to introduce techniques of tandem and feedback compensation
2. to introduce design techniques common to linear servo analysis

The primary objective of the Final Examination is to summarize the basic course structure.

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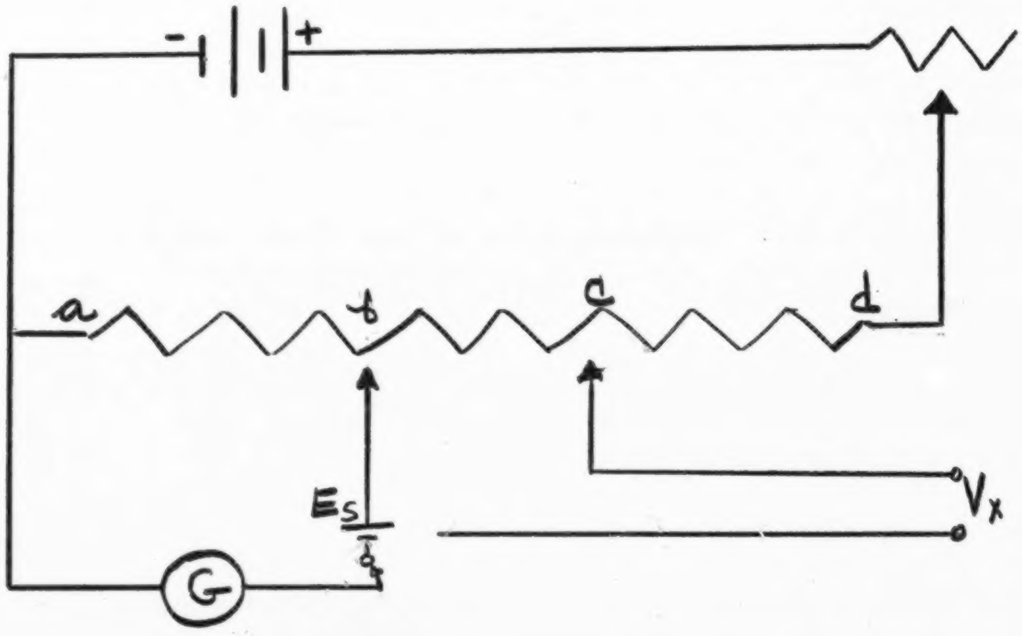
EXHIBITS FOR WORKSHOP ON TESTING

The following samples represent typical questions used in undergraduate engineering courses. They have been selected to illustrate a specific type of question and/or philosophy of testing. At the beginning of the workshop we shall review these problems or questions with a view toward establishing how they were utilized in accomplishing certain of the objectives of examinations. The participant whose question has been selected will be asked to discuss briefly the intent and accomplishment of his question.

Problem 1 - EE 211 Quiz, Fundamentals of Electrical Engineering Submitted by Professor John E. Lagerstrom, Iowa State University

(a) Suppose you had two precision resistors, one rated 100 ohms and the other 1000 ohms. Suppose you also had a precision 100 ohm rheostat whose resistance value could be read on a dial. There are two combinations of these elements in a wheatstone bridge, permitting two different ranges of unknown resistance values. What would be the largest value of unknown resistance that could be measured with each configuration?

(b) A potentiometer of moderate precision is to be built using a straight resistance wire of uniform cross section laid along a meter stick. The distance from a to d is to be one meter, and is to correspond to a potential difference of 3 volts. At what distance from a should b be placed if the standard cell has an emf of 1.018 volts?



Instructor Solution by JEL

(a) $\frac{100}{1000} = \frac{100}{x} \qquad x = \underline{\underline{1000}}$

$\frac{100}{1000} = \frac{x}{100} \qquad x = \underline{\underline{10}}$

$\frac{1000}{100} = \frac{100}{x} \qquad x = 10$

$\frac{1000}{100} = \frac{x}{100} \qquad x = 1000$

(b) $\frac{3}{1} = \frac{1.018}{x}$

$x = 0.339$ m

Problem 2 - CE 321 Hydraulics I, Quiz
Submitted by Professor Paul H. Woodruff, Michigan State University

Mark the following statements as true or false

a. Uniform flow must also be steady. T F

b. If the flow is steady and non-uniform, a streamline will also be a path line and a streak line. T F

c. In uniform flow the local acceleration must be zero. T F

d. If the flow is curvilinear and steady, the total acceleration at a point must be normal to the streamline through that point. T F

e. In a conical nozzle in which the streamlines are straight, the flow is uniform. T F

f. In a long straight channel the velocity will be lower at the sides and bottom than in the center of the cross section, nevertheless the flow is uniform. T F

g. The flow net will give a good approximation of the flow pattern in converging boundaries where the fluid is accelerating but not in diverging boundaries where the flow is decelerating. T F

h. If a flat plate is held at right angles to the flow, the fluid approaching the center of the plate will decelerate and the fluid approaching the edges will accelerate. T F

i. The flow net will only describe rotational flow. T F

j. Turbulent flow is always unsteady, but can be considered steady if the temporal averages of the velocities at every point are constant in magnitude and direction. T F

Problem 3 - Engineering 108A, Strength of Materials, Exam I
Submitted by Professor Jack Brass, University of California

A 100 foot long coaxial cable has a steel core and a bronze outside covering. The cross sectional area for the steel is 1/4"2 and for the bronze is 1/2"2.

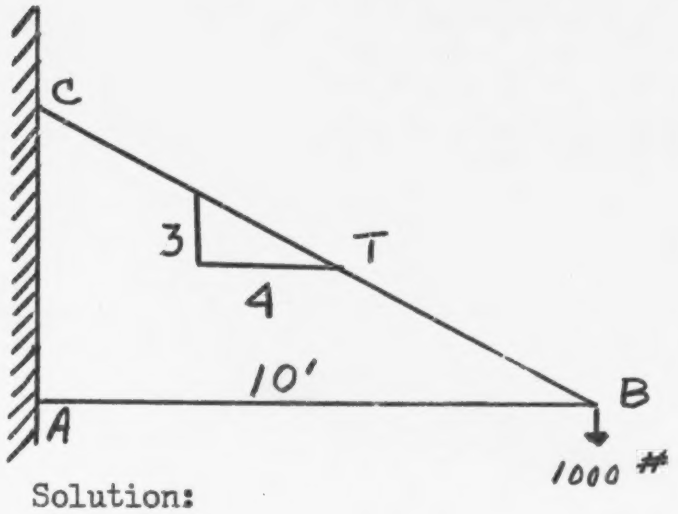
(a) Compute the axial stress in the steel and also in the bronze if the cable is subjected to a temperature increase of 20^0 F. Assume no slippage occurs between the cable core and covering and that all stresses are zero before the temperature change.

(b) Discuss why this is a statically indeterminate problem.

$E_s = 30 \times 10^6$ psi $\quad \alpha_s = 10 \times 10^{-6}$ per deg F

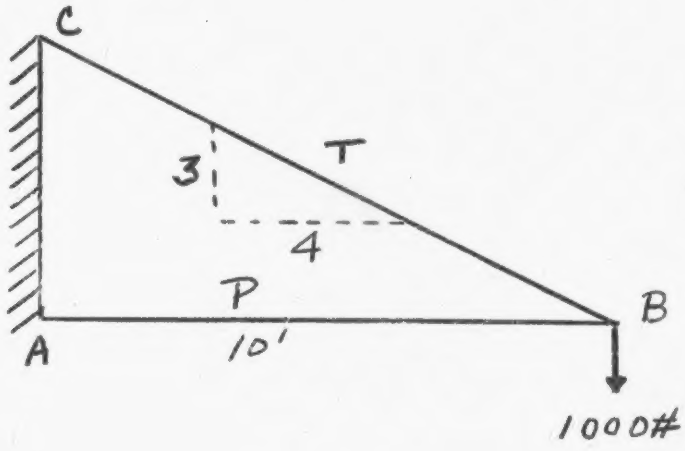
$E_b = 10 \times 10^6$ psi $\quad \alpha_b = 6 \times 10^{-6}$ per deg F

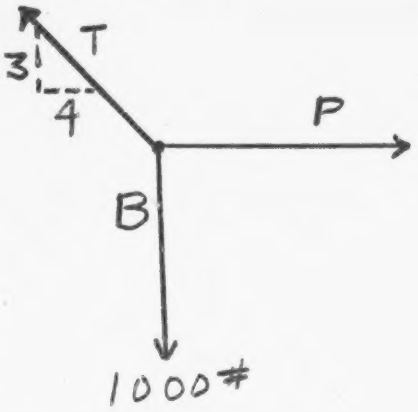
Problem 4 - CE 211 Statics, Quiz
Submitted by Professor Emmett B. Moore, Washington State University



The figure represents a load of 1000# hung from a boom AB which is pinned to the wall at A and supported by the cable BC. Solve for the stress in the boom and in the cable.

Solution:



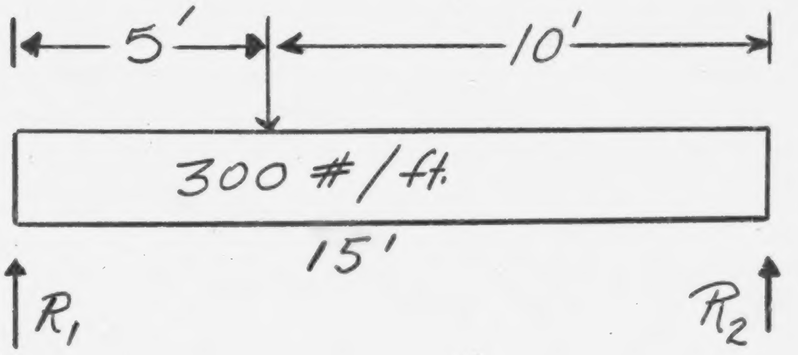


$$\Sigma y = \tfrac{3}{5}T - 1000 = 0$$
$$\Sigma x = \tfrac{4}{5}T - P = 0$$

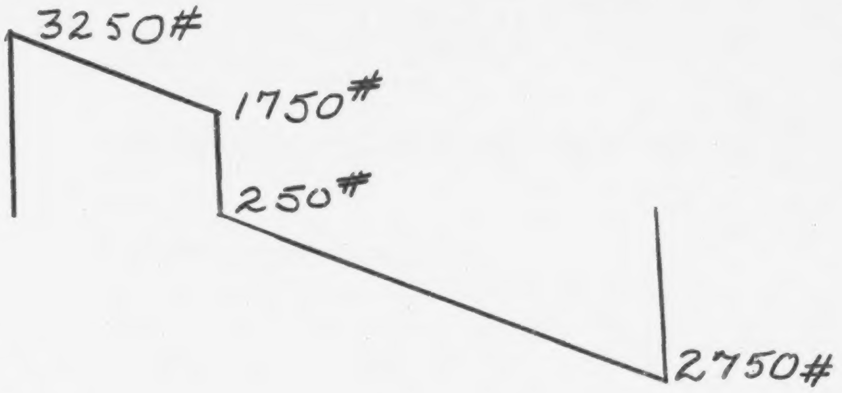
P = 1333# Compression

T = 1667# Tension

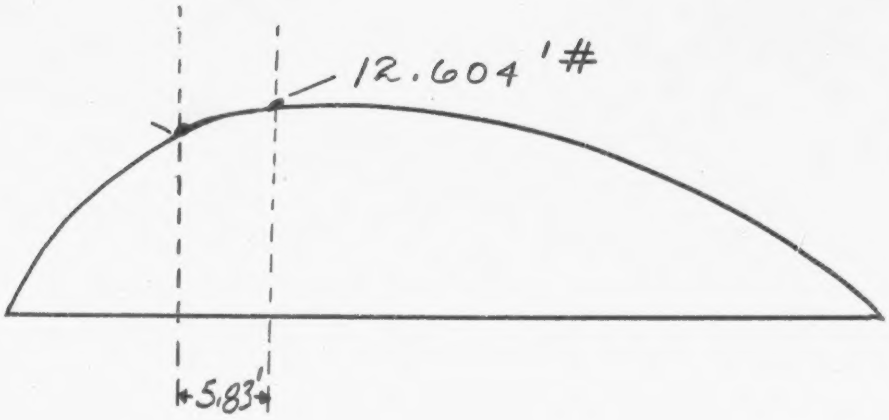
Problem 5 - CE 314, Mechanics of Materials, Quiz
Submitted by Professor Emmett B. Moore, Washington State University


5'
10'
300 #/ft.
15'
R1
R2

Draw shear and bending moment diagrams.


3250#
1750#
250#
2750#

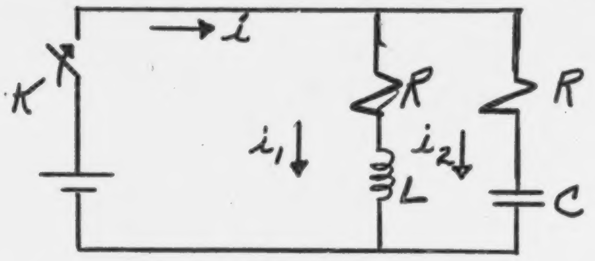
Shear Diagram



Moment Diagram

Problem 6 - EE 311 Electric Transients, Mid-term Exam
Submitted by Professor Hellmut Golde, University of Washington

A dc voltage V is applied to the circuit at t = 0.



L = 0.01 henry

C = 100 microfarad

$i_1(0) = v_c(0) = 0$

(a) Find the total current i as a function of time. (Derive the expression from the basic equations.)
(b) For what value of R is the total current i a constant?
(c) Using this value of R, what are the time constants of the two branches?

Instructor Solution by HG

Both branches are independent:

$$Ri_1 + L\frac{di}{dt} = V$$

$$i_1 = \frac{V}{R} + k_1 e \frac{R}{L} t$$

$$i_1(0) = 0 = \frac{V}{R} + k_1 \quad k_1 = -\frac{V}{R}$$

$$i_1 = \frac{V}{R}(1 - e - \frac{R}{L} t)$$

$$Ri_2 + \frac{1}{C}\int i_2\, dt = V$$

$$R\frac{di_2}{dt} + \frac{i_2}{C} = 0$$

$$i_2 = k_2 e^{-t/RC}$$

At t = 0, $V = i_2(0)R + 0 \quad i_2(0) = \frac{V}{R} = k_2$

$$i_2 = \frac{V}{R} e^{-t/RC}$$

If i_2 Const→e $\quad i = \frac{V}{R}(1 - e^{-\frac{R}{L}t} + e^{-t/RC})$

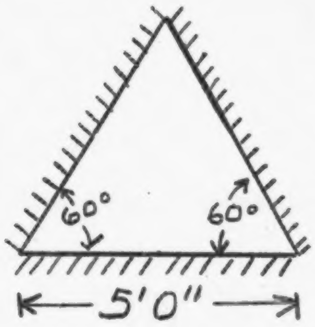
$$\frac{R}{L}t = e^{-t/RC} \rightarrow \frac{R}{L} = \frac{1}{RC} \quad R^2 = \frac{L}{C} \quad R = \sqrt{\frac{10^{-2}}{10^{-4}}} = \underline{10\ \Omega}$$

$$\underline{i_1 = i_2} = RC = \frac{L}{R} = 10 \times 10^{-4} = \underline{10^{-3}\text{ sec}}$$

II10

Problem 7 - CE 121 Mechanics of Fluids, Open book quiz
Submitted by Professor Harold S. Reemsnyder, Lehigh University

If 50 cfs of water flows through the below conduit with a pressure drop of 1 psi per 1000" of conduit, what is friction factor? (Conduit flows full.)



Instructor Solution by PW

50 cfs   Pressure drop 1 psi per 1000'

$$\tan 60^0 = \frac{h}{2.5} \qquad h = 2.5 x 1.732 = 4.33$$

Hydraulic radius $R = \frac{A}{P} = \frac{1/2\ (4.33)\ (5)}{3\ (5)} = .722$

Equivalent dia. $d = 4R = 2.89'$

Specific wt. of water $w = 62.4\#/ft.^3$

$$P_L = \frac{1\#}{in^2} \qquad P_L = wh_L$$

$$h_L = \text{head loss} = \frac{P_L}{w} = \frac{1\#}{in^2} \times \frac{ft^3}{62.4\#} \times \frac{144\ in^2}{ft^2} = 2.31\ ft.$$

$$V = \frac{\frac{50\ ft^3}{sec}}{\frac{1}{2} = 4.33 \times 5\ ft^2} = \frac{20}{4.33}\ \frac{ft}{sec} = 4.62\ ft/sec$$

$$h_L = f\ \frac{l}{4R}\ \frac{V^2}{2g}$$

$$f = \frac{h_L\ 4R\ 2g}{lV^2} = \frac{2.31\ ft \times 2.89\ ft \times 2 \times 32.2\ ft/sec^2}{1000\ ft\ (4.62\ ft/sec)^2}$$

$= .0201$ $\boxed{f = 0.0201}$

Problem 8 - ME 308 Mechanism, Exam
Submitted by Professor E. A. Bender

Given:

Vel. Scale: 1" = 30"/m

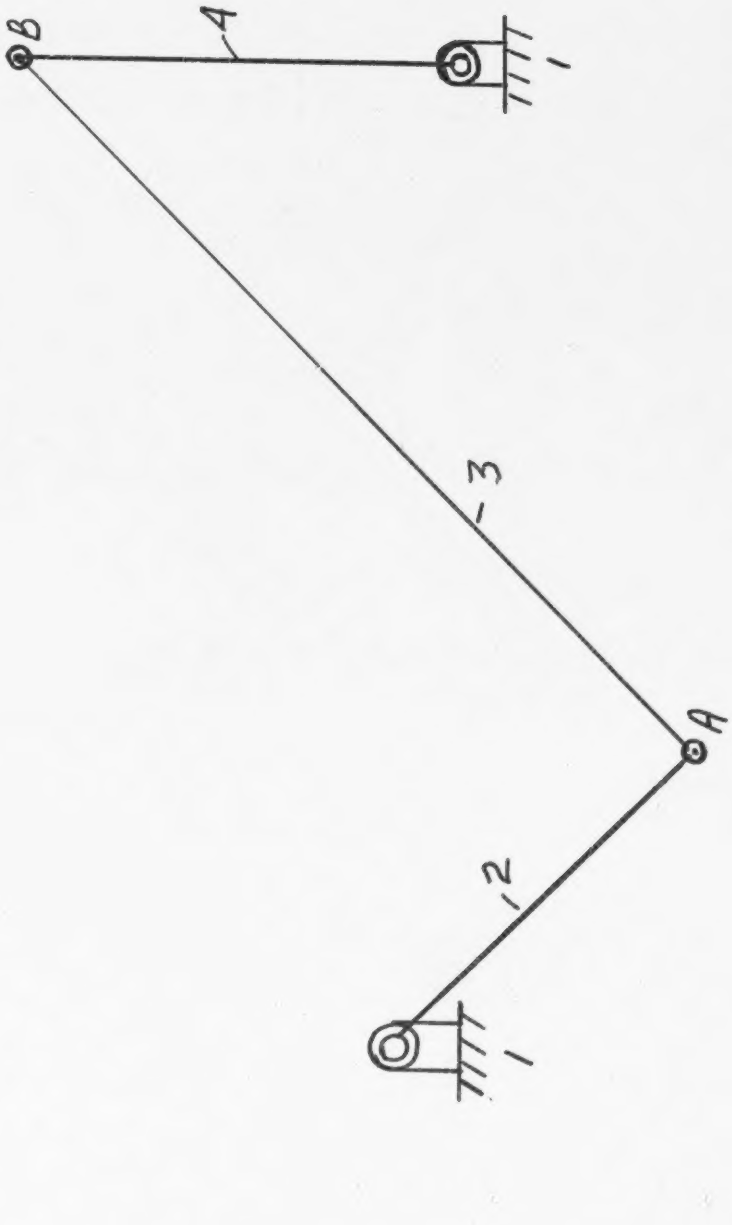
Ang. Acc. of A_{21} = 200 rad/m^2 cow

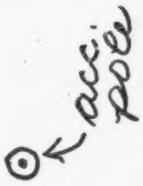
Acc. Scale: 1" = 300"/m^2

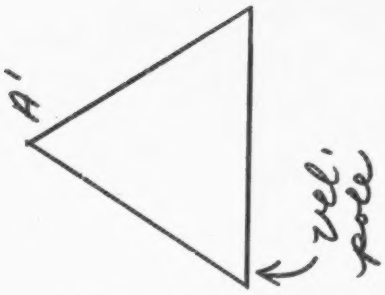
Space Scale: Full size

Find:

Acceleration of pt. B (absolute)







Velocity diagram
for given mechanism

II12

Problem 9 - CE 241 Engineering Economy, Quiz
Submitted by Professor J. Kent Roberts, University of Missouri

An antenna tower costs 1,000 dollars erected; has a life of 15 years and a maintenance cost of 75 dollars per year. The same tower can be supplied with a protective coating which will increase the life to 40 years and require 60 dollars per year for maintenance. Zero salvage in both cases. If money is worth 7% compute the justifiable expenditure for the coating. If the coating costs 700 dollars, would you recommend it?

Instructor Solution by PW

$$C = F + \frac{w}{i} \quad \frac{1}{s_{\overline{k}|i}} \qquad\qquad A_{\infty} = \frac{R}{i}$$

$$C = 1000 + \frac{9.25}{0.07} \quad \frac{1}{s_{\overline{15}|0.07}} \quad + \frac{75}{0.07} \quad =$$

$$= 1000 + \frac{1}{0.07} \quad \left[925 \quad (0.10979462-0.07) \quad + 75\right] \quad =$$

$$= 1000 + \frac{111.1002350}{0.07} = 100 + 1587.15 = \$2587.15$$

$$C = F + \frac{F-60}{0.07} \quad \frac{1}{s_{\overline{40}|0.07}} \quad + \frac{60}{0.07}$$

$$C = F + (F-60) \quad \left(\frac{0.07500914-0.07}{0.07}\right) \quad + \frac{60}{0.07} =$$

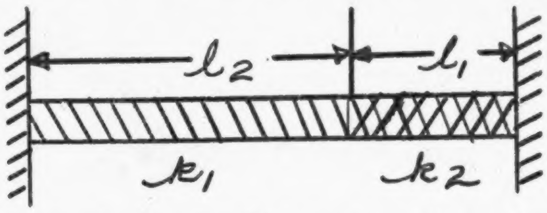
$$= 1.0715591F + 852.85$$

$$F = \frac{2587.15-852.85}{1.0715591} = \frac{1734.30}{1.0715591} \quad = \quad \$1618.48$$

$$\boxed{\$618.48 \text{ - No}} \quad \longleftarrow$$

Problem 10 - ME 242 Heat Transfer, Exam
Submitted by Professor S. Hoenig, University of Arizona

Consider a rod with an insulated surface as shown below.



Set up and solve the heat conduction equation for the temperature distribution in the rod.

Instructor Solution by PW

$$q = K_1 \frac{T_1 - T_3}{l_2} = K_2 \frac{T_3 - T_2}{l_1}$$

$$K_1 l_1 (T_1 - T_3) = K_2 l_2 (T_3 - T_2)$$

$$(K_1 l_1 + K_2 l_2) T_3 = K_1 l_1 T_1 + K_2 l_2 T_2$$

$$\boxed{\begin{array}{l} T_3 = \dfrac{K_1 l_1 T_1 + K_2 l_2 T_2}{K_1 l_1 + K_2 l_2} \\[2ex] 0 < x < l_2 \quad T = T_1 - \dfrac{T_1 - T_3}{l_2} x \\[2ex] l_2 < x < l_2 + l_1 \quad T = T_3 - \dfrac{T_3 - T_2}{l_1} (x - l_2) \end{array}}$$

←

Problem 11 - CE 140 Fluid Mechanics and Hydraulics, Final Exam
Submitted by Professor Gordon Flammer, Utah State University

Write the letter corresponding to the correct answer along the left side of the paper adjacent to each question.

1. The horizontal component of force on a submerged curved surface is equal to:
   a) the product of the pressure intensity at its controid and its area.
   b) the weight of fluid directly above the surface.
   c) the force on a projection of the surface on a vertical plane.

2. The vertical component of force on a curved submerged surface is equal to:
   a) the weight of fluid directly above the surface.
   b) its horizontal component.
   c) the force on a projection of the surface on a horizontal plane.

3. The continuity equation:
   a) relates the mass or weight rate of flow along a stream tube.
   b) expresses the relationship between energy and work.
   c) relates the momentum per unit volume between two points along a streamline
   d) states that for a real fluid, the velocity at a boundary is zero.

4. The equation $V^2/2g+ P/w+Z$ = constant has the units of:
   a) ft-lb per sec.
   b) ft-lb per lb.
   c) lb.
   d) ft-lb per slug

5. The combined pitot-static tube measures:
   a) static pressure.
   b) total or stagnation pressure.
   c) dynamic pressure.
   d) difference between dynamic and static pressure.

6. The shear stress at the boundary of a flat plate is:
   a) dP/dx
   b) $\mu dV/dy$ at $y = 0$
   c) dV/dy at $y = 0$

   x is parallel, y is normal to the plate. μ is the dynamic viscosity of the fluid and ρ is the density.

7. At supersonic velocity, the flow velocity will increase in a
   a) converging channel
   b) diverging channel
   c) straight channel
   d) flow velocity cannot increase if it is already supersonic

8. The dynamic viscosity of gases generally:
   a) increases with increasing temperatures.
   b) decreases with increasing temperatures.
   c) is independent of temperature.

II14

Problem 11 - CE 140 Fluid Mechanics and Hydraulics, Final Exam
Submitted by Professor Gordon Flammer, Utah State University

Write the letter corresponding to the correct answer along the left side of the paper adjacent to each question.

1. The horizontal component of force on a submerged curved surface is equal to:
   a) the product of the pressure intensity at its controid and its area.
   b) the weight of fluid directly above the surface.
   c) the force on a projection of the surface on a vertical plane.

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   c) straight channel
   d) flow velocity cannot increase if it is already supersonic

8. The dynamic viscosity of gases generally:
   a) increases with increasing temperatures.
   b) decreases with increasing temperatures.
   c) is independent of temperature.

Problem 12 - EE 347 Electric Circuits and Machines, Exam
Submitted by Professor Ian McCausland, University of Toronto

Describe briefly a graphical method of finding the current in a circuit consisting of a vacuum diode, a resistance and a constant-voltage (D. C.) source in series.

Problem 13 - IE 453 Industrial and Production Controls, Quiz
Submitted by Professor Scott T. Poage, Oklahoma State University

A commonly used analogy to an inventory system is a hydraulic system. Explain this comparison.

A commonly used (and often most useful) assumption in the industrial world is that total plant costs are composed of "fixed costs" which are constant regardless of the percentage of capacity at which the plant is operating and "variable costs" which are directly proportional to the capacity which is being used. List five major variations from this assumption in the real situation.

1.______________________________

2.______________________________

3.______________________________

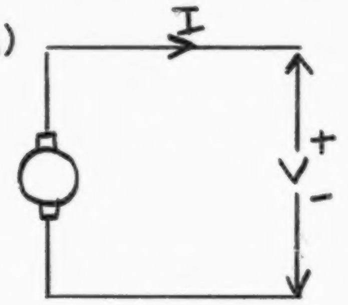
4.______________________________

5.______________________________

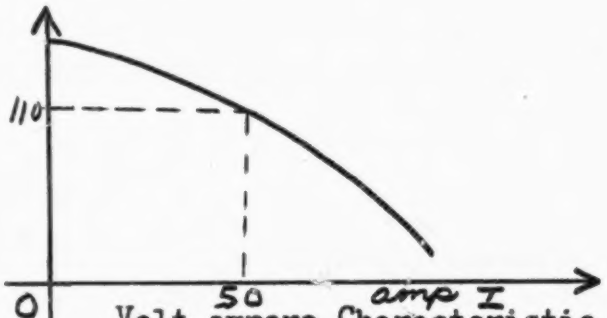
What is the difference between the "Total Value" method used by Magee in deriving the economic lot size formulas and the "incremental" method?

Problem 14 - EE 401 Electric and Magnetic Circuits, Quiz
Submitted by Professor Anthony Giordano

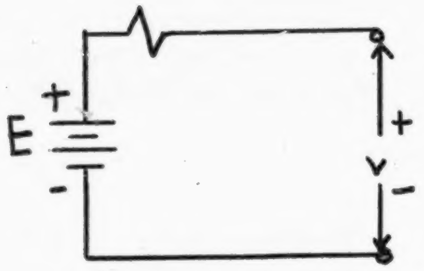
(a)



DC Generator



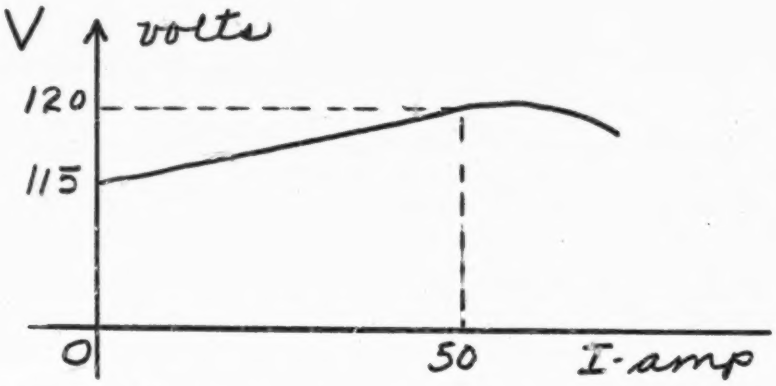
Volt-ampere Characteristic



Equivalent circuit

The generator has the voltampere characteristic shown above. The generator is to be represented approximately, for load currents between 0 and 50 amp., by the equivalent circuit above. What are the appropriate values of E and R?

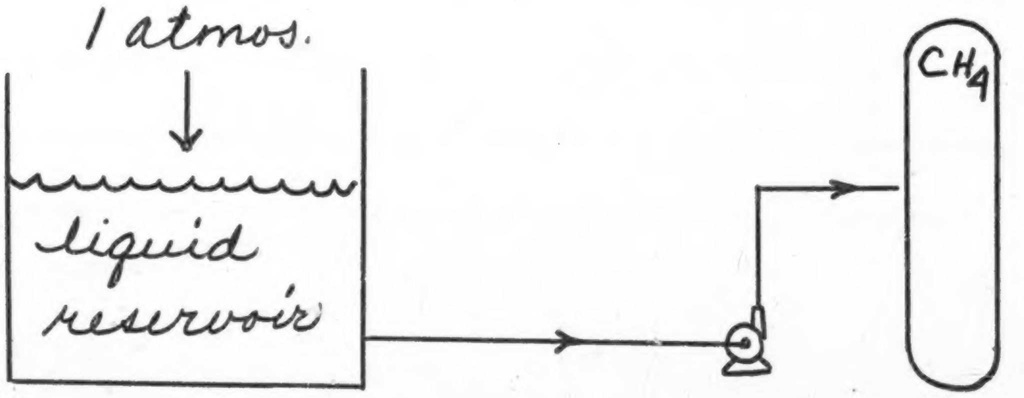
(b)



A generator similar to the one in (a) has the characteristic of the above figure. The equivalent circuit is to represent the generator for currents between 0 and 50 amp. What values of E and R are needed?

Problem 15 - Chem. Engr., Thermodynamics, Quiz
Submitted by Professor Robert S. Kapner, Rensselaer Polytechnic

Methane, CH_4, in a tank at -44° C and 25 atmos. is compressed by pumping a non-volatile incompressible liquid into the tank. The compression is carried out isothermally until the pressure in the tank is 50 atmos. If CH_4 is considered a non-ideal gas, calculate the work delivered by the pump in BTU/lb-mole of CH_4 compressed. Assume all parts of the process are reversibly performed.



Instructor Solution by RK

The work done in pumping the incompressible fluid must be equal to the work done in compressing the methane.

For the methane: $\Delta E = Q - W$ (non-flow process.)

For a reversible compression at constant temp.

$$Q = Q_r = \int T dS = T\Delta S$$

$$\text{and } \Delta E = T\Delta S - W \qquad \text{or } W = T\Delta S - \Delta E$$

$$\text{but } \Delta E = \Delta N - \Delta(PV)$$

$$\therefore W = T\Delta S - \Delta N + \Delta(PV)$$

---

for methane, $T_c = 191^\circ K$, $P_c = 45.8 \text{atm.}$

@ STATE ① $T_{R_1} = \frac{229}{191} = 1.2$

$P_{R_1} = \frac{25}{45.8} = 0.545$

$Z_1 \cong 0.9$

@ State ② $T_{R_2} = \frac{229}{191} = 1.2$

$P_{R_2} = \frac{50}{45.8} = 1.092$

$Z_2 \cong 0.78$

Since $P_2U_2 = U_2Z_2RT_2$

$P_1U_1 = U_1Z_1RT_1$

$$\Delta(PV) = P_2U_2 - P_1U = U_2Z_2RT_2 - U_1Z_1RT_{11}$$

$$= U RT_1(Z_2 - Z_1)$$

$$= (1)(1.987)(229)(0.78-0.9) \frac{\text{cal}}{\text{g-mole}} \times 1.8 \frac{\text{BTU/lb.-mole}}{\text{cal/g-mole}}$$

For ΔH and ΔS

$$\Delta H = H_2 - H_1 = {}_1\Delta H^{1}_{T_1} P + (H^{1}_{T_{L1}} P_2 - H_{T_1 P_1}) - \Delta H^{1}_{T_1 P}$$

$$\Delta S = S_2 - S_1 = {}_1\Delta S^{1}_{T_1 P} + (S^{1}_{T_{L1}} P_2 - S^{1}_{T_1 P_1}) - {}_2\Delta S^{1}_{T_1 P}$$

@ $T_{R_1} = 1.2$

$P_{R_1} = 0.545$

$_1\Delta U^1_{T_1P} \cong 0.8(Tc) = (0.8)(191)\frac{°K \times 1.8°R}{°K} = 275$ BTU/lb-mole

$_1\Delta S^1_{T_1P} \cong 0.55$

@ $T_{R_2} = 1.2$

$P_{R_2} = 1.092$

$_2\Delta H^1_{T_1P} \cong 2(T_c) = (2)(191)(1.8) = 688$ BTU/lb-mole

$_2\Delta S^1_{T_1P} \cong 1.18$

∴ $\Delta H = 275 + (H^1_{T_{L_1}P_2} - H^1_{T_{1_1}P_1}) - 688$

$\Delta S = 0.55 + (S^1_{T_{L_1}P_2} - S^1_{T_{1_1}P_1}) - 1.18$

Now $H^1_{T_{L_1}P_2} - H^1_{T_{L_1}P_1}$ = enthalpy charge for an ideal gas from -44°C,25 atm to -44°C, 50 atm.

∴ $H^1_{T_{L_1}P_2} - H^1_{T_{L_1}P_1} = \int cpdt = 0$ because $H^1 \pm H^1(P)$

$S^1_{T_{L_1}P_2} - S^1_{T_{L_1}P_1}$ = enthalpy charge for an ideal gas from -44°C, atm. to -44°C, 50 atm.

$= \int cp\frac{dt}{t} - R\ell\frac{P_2}{P_1} = 0 - 1.987\ell\frac{50}{25}$

$= -1.378$

∴ $\Delta H^{\wedge} = 275 \overset{\Delta}{+} 0 - 688 = -413$ BTU/lb-mole

$\Delta S = 0.55 - 1.378 - 1.18 = 2.01$ BTU/lb-mole-°R

& $W = T\Delta S - \Delta H + \Delta(PV)$

$= (1.8)(229)(-2.01) - (-413) + (-98.2)$

$= -513$ BTU/lb-mole of CH_4 compressed

∴ work done in compression = 513 BTU/lb-mole CH_4

STIMULATING CREATIVITY AS YOU TEACH

Eugene K. Von Fange
General Electric Company

The present technological race demands, for our success, qualities in our engineering graduates that have never before been approached on a large scale. It is most appropriate then, in fact, vital to hold seminars such as this to present the engineering teacher with the best tools and methods known to increase his effectiveness as a teacher.

However, if we go by dictionary definition, it is apparent that even the most effective "teacher" cannot instill the qualities that are required in our new engineers. "To teach" merely implies the imparting of information so that others may learn - - and such students may become no more than "walking libraries" or "glorified technicians."

We must set our sights higher - - to develop not merely as teachers but as educators, capable of bringing out the full capacities latent in the individual student. Then, and only then, more of our engineering students will later distinguish themselves through creative contributions.

While all of this may seem a trivial play upon words, the stimulation of creativity is a valid subject for consideration only when the collegiate objective is more than that of imparting knowledge.

It can be developed that anyone capable of thinking is capable of being deliberately and productively creative. That more are not is due to acquired habits and attitudes that blind them to their opportunities and/or prevent their having sufficient faith in their ideas to proceed with the activity necessary to evolve the ideas into useful form.

This is the basis for stating that the student must be "educated" as well as taught." His full mental capacities will be directed creatively only when his mind is not blocked by habits that preclude thought, or by attitudes that so filter or color and result in thinking that new concepts would not be allowed conscious expression.

Further, to be motivated to think at all, he must be challenged by the inadequacies of today's technology, rather than mesmerized by its seeming perfection. Finally, to create is to form new associations from existing elements of knowledge. To be most richly productive of ideas the creative contributor must be capable of exploring our vast knowledge resources in breadth as well as in depth.

Let us first consider the conditions necessary to encourage an engineer to undertake creative projects; second, the conditions for its effective conduct; and finally, what the teacher can do to stimulate and develop his students for later creative achievement.

The Undertaking of Creative Engineering Projects

Before a person will undertake the work of contributing worthwhile change, he must have:

1. An awareness of and belief in his own creative capabilities.
2. Faith that worthwhile advances can be made in any area.
3. A strong, purposeful desire to contribute.

Our present high standard of living is a tribute to the educators of the past and a challenge for us today to continue and even accentuate this pace. We must never rest on our laurels for history supplies ample evidence of the decline and fall of one nation after another - - once the three qualities listed became submerged in an atmosphere of smug complacency with regard to what had been accomplished.

It is in this vein that we should appraise our teaching practices, being deliberately critical so as to uncover any potential weaknesses that could, if unchecked, undermine our future growth.

Observation of a large number of engineers participating in creative courses in industry, as well as applicants for these courses, indicates several areas that merit discussion.

In engineering especially, the danger exists that with so much knowledge in the organized and tested fund, an entire curricula can be established wherein a student will never be exposed to a situation where the straight-forward application of his stock of special-case formulas does not quickly resolve the matter. After four or more years of such indoctrination, the student can easily develop a blind faith in existing theory and the engineering profession's never-failing mastery over nature. This leads easily to a conclusion that, since everything essential is now known, his best chance for success is to make the acquisition of knowledge his goal. With such a sterile goal, little more than a technician results, capable only of repeating existing technology and unaware of the responsibility of the professional engineer to advance the existing state of the art.

This kind of attitude, while fortunately disappearing after a few years, is readily observable in many young engineers. It is so pronounced in some that they are startled and somewhat amused when asked whether they would like to enroll in a course to develop their creative capabilities. With their one-problem, one-solution background it is self-evident that all essential problems have been solved.

For those whose knowledge of the creative process consists of only newspaper accounts where, to attract interest, the emphasis is on the bizarre, the mysterious, or the great "flash," the rationalization that "creators are born, not made" is readily formulated. This passivity, however, completely blinds them to their creative opportunities. We find only that for which we are actively seeking. Students must be acquainted with the creative process and some of the logic of creative thought if they are to become aware of their full capabilities.

Finally, when courses become too well-evolved and sifted of error and the assigned problems too free of any circumstance preventing a solution, the students are not conditioned to face failure. Now it is inherent in creative work that the outset the creative engineer does not know how to solve the challenge facing him. He realizes that a number of false trails must necessarily be explored before a fruitful one is conceived or discovered. His possession of the three qualities listed causes him to initiate activity even though he knows his first efforts will, in all probability, fail. Contrast this with the attitude of a student to whom failure means loss of prestige and a flunking grade. Unless this attitude is corrected, he is likely to run away from a creative challenge if he should happen to find one glaringly exposed to him.

To summarize, the mental capacities of the student that render him capable of creative achievement are much like a wonderful natural harbor. Our educational system may be likened to building roads and railroads and factories to permit full use of this harbor. It takes a ceaseless vigil to prevent such engrossment in this peripheral effort that the harbor itself becomes forgotten and through neglect covered over by drifting sand.

The Effective Conduct of Creative Projects

To secure the greatest opportunities for successful completion of creative engineering projects the following additional requirements merit attention:

1. The "needs" of the situation must be identified and explored at the outset.
2. One's power of judgment must be well-developed.
3. The ability to generalize requirements and build from fundamentals must exist.
4. One must be skilled in the full exploitation of our diverse and vast storehouse of recorded knowledge.

The engineering mind typically enjoys precision, conciseness, and logic. The engineering teacher and authors of engineering texts will take great care to insure that problem statements include no more and no less than is essential to secure the solution. The student quickly learns that it is pointless to question assignments. This belief can and often does stay with him upon his entry into industry, and it is rather characteristic for him to begin blindly with whatever specific instructions are provided at the outset of his projects. He may quickly uncover evidence to indicate that some changes in direction or scope are in order. However, since assignments "are never wrong" he may feel that he does not yet understand what is required and will therefore keep quiet about it. Some time can elapse before even an alert supervisor will sense the difficulty and redirect the effort.

The most challenging aspect of many creative projects is that of defining, clearly and precisely, what is desired. It may be somewhat later before these desires can be reconciled with what is actually attainable as a solution. One can, in the process, literally become inundated with data, opinions, and ideas, many of which will overlap, be contradictory, or will later be shown to be inapplicable. The engineer who has never before been exposed to such nebulous assignments may well withdraw at the first opportunity and retire to the security of a routine engineering position.

Another potential difficulty is that as one increases his effectiveness as a teacher, he increasingly removes the opportunities for his students to exercise judgment - - unless he remembers his responsibility to educate as well as teach. Although it has been said that "not one man in a thousand has imagination," it is more accurate to state that not one man in a thousand has a sufficiently active and developed power of judgment to direct his imagination profitably towards creative problem solving. Our imagination is ready to do our bidding at all times - - whether for daydreaming, rationalizing, conceiving new sarcasms or witticisms, or for generating new ideas to study as possible solutions to problems. What often passes for judment is no more than a keyed response and if one has a good memory he can often get by.

As one psychologist phrased it, our mind is no more than an "Emergency Organ," that we reduce all new situations as quickly as possible to an unthinking routine and that we do not feel really comfortable in a new job until we can go for extended periods without having to think at all.

In creative work, our power of judgment directs the activity. Since it is the mental power that is discriminative, that senses relationships and values, it cannot function or be exercised in any circumstance where a freedom of choice does not exist. Curricula, laboratory, and classroom practices and content must be closely watched in this respect to insure that this wonderful mental power is not allowed to become calcified through neglect.

In creative engineering work one typically has no text or teacher to point the way or to define the scope of knowledge pertinent to a solution. In effect, therefore, the preceding paragraphs state that an "educated" engineering graduate is one who has been led progressively away from dependence on teacher and text in his problem-solving activities.

As a final item, as texts are evolved for an engineering curricula the point is reached where the student can assume that everything he studies in a text is correct. While this is efficient in acquiring useful knowledge it does allow the condition to develop where the engineering student will no longer find it necessary to develop himself into a critical reader. If this attitude is acquired he will later view the engineering practices in his job or as recommended in various references as THE way and be blind to his chances to contribute creatively.

Further, if his problem solving experience is confined to the material in his textbooks he can graduate virtually ignorant of the use and worth of the vast resources available to him in libraries and elsewhere. In the extreme, he will view as impossible a problem that cannot be quickly solved through reference to a single source.

Developing Creative Engineering Capability

When the psychologist mentioned earlier began experiments on his students to test his theories he found that as long as they could keep on doing the things they had always done their minds wouldn't work. It was only when he "stole their notebooks, upset their routine, threatened them with failure" that any thinking was done. The following compilation of additional suggestions may serve to initiate discussion on specific ways to stimulate creativity within existing course frameworks:

1. Expand use of journals, patents, references.
2. Employ multiple texts.
3. Cover thoroughly the history of events leading to the existing state of the art.
4. Summarize at intervals what the subject matter can do, but more important, circumstances where it is inadequate and where further innovation is in order.
5. Set a purposeful example, yourself, as an educator through research activity, community service projects, etc.
6. Act dumb, once in a while - - be free in the use of the expression "I don't know."
7. Conduct discussions of major contributions to uncover possible answers to the question "What could have led him to the idea?"

8. Give students responsibility as discussion leaders.
9. Present plausibly major errors in concept.
10. Assign class to hypothesize reasons whenever a classroom demonstration fails.
11. Eject extraneous data as plausibly as possible into assignments and examinations.
12. Interweave exercises from preceding chapters and/or earlier courses.
13. Omit assumptions.
14. Utilize "Open Book" examinations.
15. Assign students to submit their own detailed procedure and material requirements for laboratory experiments.
16. Encourage active participation in extra-curricular activities where the potential for attacking multi-solution problems of immediate worth exists.
17. Study the logic of creative thought.

COURSE AND CURRICULUM PLANNING

G. A. Hawkins

Purdue University

I. Introduction

Course and curriculum planning present complex problems, with many variables, which are very difficult to solve. Before taking up this subject, it is necessary to consider some of the most important and basic concepts of education.

II. Basic Educational Concepts

A. Education is a Self Discipline

Education is essentially a self discipline[1 & 2*] for which the individual must assume the major responsibility. The primary function of the teacher is to establish a scholarly atmosphere in which the student will strive to learn. Courses, curriculum, laboratory facilities, classrooms, etc., are of little value if the spirit of inquiry is not stimulated. One of the finest examples of establishing the correct atmosphere is presented in the story of Helen Keller's[3] education.

B. The Lifelong Learning Process

Let us start our consideration of the lifelong education of the engineer at the time when he enters a formal freshman engineering program in a university or college. The four- or five-year period he spends in an engineering educational institution will be termed the introduction to professional engineering. Commencement is exactly what the word implies, the beginning of his professional engineering career, which will cover a period of at least forty years. The time spent in college is approximately ten per cent of the time he will devote to engineering as a profession. This is most significant since his learning period, after graduation, will be ten times as long as that of his formal university education. If the professional engineer is to continually enhance his stature, he must accept learning as a lifetime process.

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*Numbers refer to references appended.

The importance of lifelong learning may be emphasized by the attitudes of some of our engineering graduates. The opinions expressed by former graduates may, in general, be grouped in four categories, each being associated with the approximate number of years elapsed since his graduation.

During the period from one to approximately five years after commencement, some of our young men feel that their programs of study should have included much more in the way of practical courses. With a program of this type, they feel they could have started off immediately solving the day by day problems confronting them in their professional career. The second group consists of those who have been out of college five to fifteen years. These graduates feel that they should have had many more courses in mathematics, physics, chemistry, and the engineering sciences, as they need this type of information for the solution of their difficult engineering problems. The third group, having been out of school between fifteen and twenty-five years, have become involved in management and administration. They are quite positive in expressing their opinion that they should have been given many courses in organization, English, report writing, public speaking, labor relations, finance, budgeting, stocks and bonds, and investments. The final group consists of those who have been away from college for approximately twenty-five years or more. Those in this group appear disappointed that few courses in their college career were devoted to the fine arts, music, literature, drama, and world cultures. These are the areas in which they feel deficient when talking to their contemporaries.

It would not be possible for those in engineering education, in a four- or five-year program, to give students who elect engineering work as a career, a knowledge of present-day practice, a strong foundation in the physical and engineering sciences, a broad education for management and leadership, and an appreciation for the arts, literature, and music.

Let me hasten to add, however, that those engineering graduates of ours who have adopted a philosophy of lifelong learning during the course of their professional career, ultimately acquire this type of total education. I could cite many of our graduates who have never once stopped their learning experiences. I fear that many of those who complain have not chosen to regard learning as a lifelong process, and that they are not or have not been willing to put forth the effort required by such a philosophy.

Consider next the responsibility of the educator, of industry, government, and other agencies, and of the engineer as an individual in this lifelong learning[4] process.

1. Responsibility of Professional Educators

Those of us in engineering teaching must assume the major responsibility for the formal university four- or five-year program and for graduate study as well. We as educators, must stand ready to assist industry, or the individual, when necessary, by offering formal courses in engineering as well as in the general area of adult education.

2. Responsibility of Industry, Government, and Other Practitioners

The obligation to provide for the continued improvement of the engineer is very great since it covers his entire professional life span. Again, we must emphasize that the responsibilities of industry, government, and other agencies, and of the individual engineer, cover a period of time approximately ten times longer than that of the university educator.

3. Responsibility of the Individual Engineer

One of the most important elements in the lifelong education of the engineer is the recognition by the individual himself that learning is a self discipline. As an engineer advances in age, his interests will change: for example, he may have significant management responsibility for which he lacks the necessary background. If the lifelong learning spirit has been instilled in him he will undertake to expand his learning in these fields in advance of the time of actual need for the knowledge by reading, engaging in correspondence courses, etc.

C. The Product

Engineering teachers must not forget for a moment that we are educating students for industrial, governmental, and other occupational functions. If the needs of these groups are not adequately satisfied, then the present programs of study must be re-evaluated, and, possibly, new programs provided.

D. The Students

The educator must recognize that there are various types of students, and provide an educational program which will challenge each one to perform at his maximum capacity. For purposes of discussion, let us divide learners into three general groups: namely, pupils, regular students, and scholars. Pupils are those who are beginning their educational work and are under the rather close supervision of a teacher or tutor. Young men in this group would generally be found in the freshman and a part of the sophomore years. The programs of study should be such as to provide a proper academic atmosphere, adequate supervision, and clear direction. Pupils finally emerge as regular students and scholars. The great mass of junior and senior students may be characterized as the normal or regular student. These young people should be motivated to perform to their maximum capacity. The very superior students are to be termed scholars, whose numbers are far too few. These students need special direction in order to keep their thirst for knowledge at a high level. A scholar forced through the more or less routine programs of the typical student, may become discouraged even to the extent that his potential growth may be completely subdued.

III. Some of the Forces Which Tendto Influence the Engineering Educator in Establishing the Academic Environment, The Program of Study, and the Courses.

A. The Ever Changing Sciences and Technologies

Even prior to 1940, important scientific developments began to place new demands upon the engineer's skill and knowledge. In order to cope with the new problems in electronics, the electrical engineer needed a deeper understanding of physics. An increasingly large body of scientific information was required of the civil engineer in the study of structural problems as related to the welding processes, vibrations, and the unusual soil conditions encountered. Mechanical engineers were confronted with new problems in heat transfer, thermodynamics, and fluid mechanics, as a result of the expansion of work in gas turbines, and in rocket and jet propulsion, all of which required new methods of analysis and a better comprehension of physical phenomena. Metallurgy was changing from an art to a science as it was being built ever more firmly upon the foundations of physical chemistry and physics of the solid state. These new developments, together with many others, were causing a revolution in the practice and were demanding an evolution in engineering education programs. The advent of new scientific and technological developments has caused a profound change in the type of trained men sought by many industries.

The new digital and analog computers, in opening up vast new areas of calculation procedures for the engineer and scientist, have placed new responsibilities upon the engineering schools to make certain that students have an appreciation of the great usefulness of these new tools.

We have pierced the sonic barrier, and man now flies at speeds far in excess of that of sound. But with the ever increasing speed we are confronted with a new barrier, the "thermal barrier," in which the problems become even more complex as the speed increases. The effect of friction heating at high speeds has been observed for generations in the sudden flash of a particle from outer space as it enters the earth's atmosphere and there vaporizes. One of the serious problems in the design of intercontinental ballistic missiles was that of re-entry into the atmosphere.

All of these developments and particularly the increased utilization of atomic energy has resulted in a need for an integration of learning in the technical field which certainly must start in the undergraduate engineering programs. In the design of nuclear reactors, information from all areas of engineering must be brought into use.

Perhaps the best way to illustrate the urgency of the present need for modifying the educational programs to keep pace with technological change is to point out the decrease in the time gap between scientific discoveries and their applications. For instance, the time that elapsed between the discovery of electro-magnetic waves and the production of the first radio sets receiving commercial broadcasts was considerably longer than the time interval between Dr. Otto Hahn's discovery of nuclear fission and the explosion of the first atomic bomb.

B. Varying Attitudes of Industries

Some industrial representatives, when interviewing students, stress the importance of programs which emphasize the physical and engineering sciences, others the importance of the student having a knowledge of present-day practice, while still others hire men from non-engineering fields, educate them for varying periods of time, and then classify them as engineers.

C. Attitudes of Former Graduates

Many graduates of engineering schools return to the campus and express their views on their educational programs in a multitude of ways.

D. Attitude of Individuals Outside of Engineering

Many of those in the field of the liberal arts feel that the engineering student should have many more courses of a cultural nature. In all probability the liberal arts students should have more courses in science if they are to understand the impact of scientific and technologic advances on society.

E. Influence of E.C.P.D.

The policies established by E.C.P.D. regarding accreditation of engineering programs influences the design of curricula. During the past ten years, considerable emphasis has been placed by the E.C.P.D. inspectors on increasing the scientific content of engineering curricula. As a result of this attitude, many engineering programs have been upgraded.

F. Influence of A.S.E.E.

Studies sponsored by the A. S. E. E. have had a significant influence on the planning of the engineering programs also. For example, the report of the Committee on Evaluation of Engineering Education, published in 1955, has served as a guide to many engaged in engineering curricula planning.

G. Attitudes of Professional Engineers

Many engineers want to maintain a rigid adherence to traditional professional lines of demarcation, i.e., Mechanical Engineering, Civil Engineering, etc., and resist changes in engineering programs which would deviate from this pattern. This attitude extends to some engineering teachers. At times, this leads to a feeling that they are better able to teach subjects in fringe areas themselves. This in turn tends to draw a major number of courses within a more narrow sphere of influence.

H. Attitude of the Public

The confusion in the minds of the general public as to the distinction between the work of the engineer and the technician influences the design of engineering programs.

I. Human Resistance Against Change

In spite of enormous changes in technology and science too many of our engineering teachers tend to resist changes in programs of study, hence progress is often retarded.

J. The Sacred Cows of Education

With the passage of time, certain concepts develop and are accepted, which may or may not be based on facts. These "sacred cows" may have a marked effect on curriculum planning. Many of our colleagues feel that the fifty-minute class period is the ideal. Do we really know whether or not this time period is the best from a pedagogical point of view? Some contend that the optimum class size is about twenty-five students. Do we know this to be true? Considerable experimentation needs to be carried out to study some of these concepts, and if they are found false they should be discarded.

K. The Four-Year vs. The Five-Year Program

Curriculum planning is influenced by the length of time devoted to the curricula. We have four-year and five-year programs in engineering today. The difference between these programs is quite pronounced in some cases.

L. Russian Engineering Education

We must be aware of the type of engineering education that exists in Russia, since our students will be competing with these graduates in the years ahead. We must make certain that our curricula challenge the students, so that educational development will be maximized.

M. Increasing Complexity of Engineering Systems

The complexity of engineering systems is increasing in all aspects of the engineering profession. Many examples could be cited but only a few will be mentioned. In the electrical system of the P-51 fighter aircraft there were 515 wires totaling a length of 1,545 feet. In the present F-86 there are 5,500 wires which would stretch 22,916 feet. The man hours of maintenance required per hour of flight for the B-29 bomber was approximately 55 hours. For the B-52 this has increased to 120 hours. The problem of sewage disposal of radioactive wastes has placed new demands on the sanitary engineer.

IV. Establishing the Objective

During the past several years considerable confusion and many differences in opinion have arisen in discussions dealing with the remodeling of engineering curricula. The problem is complicated by those who are advocating more solid state or modern physics, more industrial management, and more of this and that. As a result some are redesigning programs of study simply by reshuffling courses, adding one or two and removing others in a manner which is not based on sound engineering analysis and synthesis.

As engineers we should design the educational program in the same way that we would design any complex engineering system. First let us define the problem, establish the fundamental elements, design the program, and develop courses to accomplish the objectives.

In order to proceed with the discussion, engineering will be defined[5 & 6] in the following manner:

Engineering encompasses the application of various principles and concepts of the physical and life sciences and background knowledge (the basis of the art of engineering) to the study, design, and operation of systems composed of structures, energy converters, circuits, processes, or combinations of these elements; and the analysis, synthesis, and prediction of their behavior under specified working conditions in terms of men, materials, cost, and time.

A. Characteristics of Professional Engineering

What are the characteristics of professional engineering? For this part of the discussion, I must include information furnished me during personal conferences with Dean A. A. Potter, Dean L. M. K. Boelter, Dean S. C. Hollister, and many practicing engineers. A composite opinion indicates that some of the characteristic requirements and situations which confront professional engineers are:

1. The problems needing solution by professional engineers are specific in nature. This is not always the case with the scientists; they are often free to search out a theory which interests them.

2. Professional engineers are always required to meet deadlines. They must reach a decision during a specified time interval. In general, time does not play so vital a part in the work of the scientist.

3. Professional engineers are almost always obliged to work closely with other people who have not been trained as engineers. Due to the complex nature of their problems and the many social factors involved, engineers often work as members of a team. For example, the design of a dam requires, in addition to the services of the engineers, assistance from geologists, economists, metallurgists, and many others. The scientist on the other hand often works alone or mainly with other scientists.

4. Professional engineers must devote their attention to problems which they know will affect the lives of men in the future, while the technicians deal mainly with the problems of the day. The early civil engineers who laid out the railroads affected the lives of men for generations; since, in designing the routes, they indirectly established the locations for some of the great cities of today.

5. Like other professional men, the engineers must accept the responsibility of lifelong learning in order to keep pace with technical and social advances in their area of interest.

6. Professional engineers also must develop a keen sense of values and standards. Appreciation of human, moral, social, asthetic, economic, professional, and of many other values is a necessary part of the engineer's make-up.

These are only six of the main factors which characterize and in some respects distinguish professional engineers and their work; they should be kept in mind, along with the definition of engineering, during the remainder of this discussion.

B. Other Functions Performed by Engineers

There is no doubt that the education received by engineering students prepares them to perform with significant success many functions other than engineering. Many engineering graduates have distinguished themselves in fields outside of engineering, and a great number have risen to high executive positions.

The feeling has grown, especially among this group, that the subject matter of instruction should be changed to contain more knowledge of the actual procedures of management--even of top management--of finance, marketing, inventory control, etc. This influential opinion has had the effect in some instances of diluting the engineering programs with courses not directed toward meeting the main objectives of engineering education. The question then naturally arises: What percentage of graduating engineers actually pursue engineering work?

It is most difficult to acquire data relative to the classification of the work of engineers in industry and other organizations due to the time factor involved. As a result of an exhaustive survey of the engineering graduates of Purdue University,[7] it seems clear that their work covers a broad spectrum of activities in engineering. All of the functions in engineering are important in our modern society; and each engineer has his own particular tasks to perform. The results of their combined labors account in large measure for the great industrial growth of America.

C. The Dilemma of the Curriculum

Engineering educators often find themselves in an apparent dilemma! They are asked to set up a curriculum that will provide education for several classes of engineers as well as for those who have no intention of entering any area of engineering. The difficulty is further compounded by the fact that many of the students are not mature enough even as seniors to decide what their particular life work shall be.

Many of the concepts thus far presented appear in interesting and humorous form in the text entitled, "The Saber-Tooth Curriculum."[8]

One might offer the following tentative proposal to meet this seemingly difficult problem of planning educational programs. Let us provide the basic education needed for professional engineering, knowing well that many more such professional men will be needed in the future and in the belief, so largely confirmed by past experience, that such education--as much as can be comprehended--will be of the greatest value to all "classes" of the engineering "fraternity" as well as to those who wander from the fold of engineering.

V. The Design of Courses and Curriculum

Usually the design of a program of study consists first of planning a series of subject matter areas which are intended to develop a background of knowledge essential to the engineer. The second stage involves the planning of the individual courses in these areas. Both steps must be carefully integrated to avoid serious duplication of effort. At the same time, ample opportunity must be provided to enable the student to familiarize himself with the objectives of the entire curriculum.

VI. Various Design Procedures Used For Engineering Programs of Study

A. Curricula Planning Based on Certain Elements[9]

A program of study could be established on the basis of elements essential to the total education of engineering students.

The first of these is the learning process. Under this heading should be considered motivation. Many of our freshmen engineers arrive on the campus with enthusiasm for the engineering profession. Instead of keeping their interest in engineering at a high level, the total effect of their college experience seems often to reduce it.

Next come the laws of learning.[10] Few of the freshmen have a clear understanding of the learning process, which includes such items as proper study habits, retention curves, etc. In order to introduce them to these important matters and at the same time strengthen their interest in engineering, we should consider using such concepts as a circuit analogy, etc. In so doing we will be able to show the importance of these essential factors in terms of an engineering system.

The student should be exposed to many experiences in deductive and inductive reasoning starting in the freshman year. It is felt that by careful integration of subject matter considerable success may be achieved. Every effort should be made to impress upon each student the importance of education as an individual affair. Too many of our graduates feel that commencement is the terminal point in their education.

The second basic element to be considered in the design of the engineering curriculum is the development on the part of the student of a keen appreciation of the languages of engineering. The basic language is, of course, the native tongue. A reading knowledge of one or more foreign languages would be advantageous. One of the fundamental needs, therefore, is greater facility in the use of English--both oral and written.

The pictorial aspects of the modes of expression by engineers are drawing and sketching. Engineers need not devote hours to the development of skill in producing precise drawings, as this is becoming the realm of the technical institute graduate known as the draftsman. Engineers should be proficient in sketching so that they can rapidly portray their ideas to the draftsman or machinist.

The symbolic phase of the language of engineering consists of the students' skill in mathematics as applied to engineering. Mathematics is a tool used by engineers, and as such should be taught as an application course.

The third design element of an engineering curriculum is the understanding of natural laws and concepts. Greater integration of subject matter is required in the basic engineering courses. The natural laws presented in physics, chemistry, psychology, etc., should receive greater emphasis in courses that follow.

In some of the technical courses considerable time is devoted to studies of existing engineering equipment. Our goal should be to develop capable engineers for the design projects of tomorrow. The plant, the machine, the device of today may become obsolete; hence, time devoted to detailed descriptions could be more effectively used to enhance the student's understanding of basic principles.

The fourth design element is appreciation of engineering as defined.

Engineering is both an art and a science. All problems in engineering are not solved by means of equations or technical data. In many instances a great deal of experience is required. Oftentimes the force fields are so extensive that one cannot deal with them by analytical methods. For example, in making the final selection of the site for a dam the chief designing engineer must utilize his wealth of background knowledge together with the information from reports prepared by such specialists as geologists, soil mechanics experts, meteorologists, structural designers, economists, electrical distribution engineers and flood control authorities. In a four-year undergraduate study program, it is not possible to do much more than illustrate the art of engineering; however, the student should be made aware of its importance.

The fifth design element is the general mode of analysis.[11] Ideal and actual systems should be distinguished from one another.

The essential steps of the general mode of analysis are: (1)preparation of statement of the problem; (2) establishment of the ideal system; (3) specification of the boundary; (4) application of fundamental laws and knowledge; (5) prediction of the behavior of the actual systems, and finally (6) study of additional systems. Of course, the general mode takes on special forms in particular areas of application.

There are four general methods of attack: experimental, analytical, the use of models and analogs, and finally what might be called art. By art we mean the application of judgment based upon experience.

The sixth "design element" is that of laboratory experiences. During the four-year program the student should work in many different laboratories, ranging from the open campus in which he might perform his surveying work, to the power plant where he may study a complete engineering system.

The seventh element is knowledge of the properties of materials used by engineers. The engineer is always confronted with the wise use of materials, and, in addition, he must eventually have an understanding of their costs and availability. Throughout his educational program the student should receive instruction with respect to the many types of materials used in the fabrication of engineering systems.

The eighth element is skill in mensuration and computation. The engineer should be required to be familiar with various types of measuring and control instruments and their use. The proper measurement of such variables as time, distance, area, pressure, temperature, resistance, voltage and flow is a vital part of the engineer's storehouse of knowledge. During any laboratory period the student should take every opportunity to acquaint himself with all types of instruments, such as electron microscope, spectrograph, oscillograph, transit, chronograph, and strain gage equipment.

The engineer is constantly confronted with several systems of symbols and units used for the designation of the physical quantities. Since no standard set of symbols or units has been agreed upon by all engineers, the student should begin to develop skill in transferring from one system to another. He should be encouraged not to complain when one instructor uses one set of units and another a different one. He must accept this as a challenge to develop skill in understanding all of them.

By their very nature engineering problems require computation; hence, skill should be developed in the use of computers. The engineering student often starts to use a computer in the sophomore year, the slide rule. He should be encouraged to become familiar with all types of computers in use on the campus during his stay at the university.

The ninth element is knowledge of regulation and control. All modern engineering machines, processes, and circuits involve some kind of control or regulating instruments. The student should be encouraged to study the types of instruments and controls used in all parts of systems, and the role they play in system control. For example, in a modern automobile one finds: the ignition and light switches, gearshift mechanism, speedometer, oil gauge, battery charge or discharge meter, fuel gauge, etc. The student should be able to understand the use of each in the control of the total system, in this case, man and his automobile.

Many opportunities should be afforded the student to observe control systems in the laboratory. Inspection trips should be arranged to industrial plants for the study of actual regulation and control systems, as well as of industrial processes.

The tenth element is acquaintance with industrial processes. Modern industry uses a multitude of processes for the manufacture of end items. It is essential that the student have an appreciation and understanding of some of these. In the limited time available, it is possible to introduce the student to only a few of them in laboratories, such as the manufacturing process laboratory.

Students should be encouraged to take full advantage of inspection opportunities and to seek summer employment that will enable them to become acquainted with the operation of some of the important induatrial and service processes.

The eleventh element is appreciation of values.[12] Before he can enjoy the status of a respected citizen in his community and become a worthy member of his profession, the engineer must have developed an appreciation of certain values: human, moral, social, artistic, economic, and professional.

He should endeavor to understand the actions of those about him and try to realize why they behave as they do in meeting the problems which confront them. And with this understanding should come good will! He should seek to recognize and to cultivate truthfulness--honesty--integrity--especially in intellectual areas such as his own work. He should develop a strong sense of loyalty--to his fellow workers, to his employers, to his profession, to his country. He should contribute his best effort toward the various worthwhile co-operative undertakings in his community. He should develop an interest in school systems, local governments, etc. As a good citizen, he should study current events and take seriously his obligation to vote. He should seek an understanding of music, art, drama, etc. This will help him to appreciate the aesthetic qualities of his own work as an engineer. The student should develop an appreciation of economic values; for example, the value of new discoveries and inventions. Indeed, without this he cannot be an engineer. Every student and engineer should have a pride in his profession and contribute ideas that will help to enhance the standing of engineering. The student should be encouraged to join a student engineering society before graduation and to take part in its activities, seeking, if possible, to improve them.

The sense of value is an awareness and a conviction that one gets from others who have it. It can be shared but not legislated into existence. The opportunity of the college to help the student in this area therefore depends primarily upon the teachers--the quality and intensity of their sense of values; the curriculum, itself, is of secondary importance.

The final element is the integration of subject matter for design. As the student progresses he should be encouraged to be on the lookout for ways and means for correlating and integrating fundamental knowledge. The more of this he can do the stronger his foundation will be. For example, there are certain basic laws and relations which describe the flow of electricity in a circuit; many of whose equations apply also to the flow of a fluid through a pipe or the flow of heat through a building wall. The techniques for solving the one set of equations are, of course, essentially the same as for the others.

When or if we succeed in combining in proper proportion and emphasis the twelve basic elements herein proposed, then we shall have developed an appropriate curriculum for the engineers of the unpredictable but almost certainly trying times just ahead.

B. Curricula Planning Based on an Information Ordering System

Program planning based on an information ordering system is exemplified by the study in the Department of Engineering at the University of California, Los Angeles. The objective of this study was to uncover the essential features of an existing curriculum and display the resulting information in such a form that decisions could be made by the faculty concerning future curriculum changes or alterations.

This study required the gathering of information from each course in the program and categorizing the data. The information presented to the students in each of the courses was organized into the following general classifications:

1. Principles
2. Laws
3. Concepts, percepts, and definitions
4. Methods and modes of analysis and certain skills
5. Tools
6. Factual data
7. Applications

A large display board covering three walls in a room indicated for each course those classifications which were included in the course. The data was also placed on I.B.M. punch cards so that various types of correlations and tabulations of the information could be obtained.

Data from studies of this type will then be used by the faculty to plan the curriculum changes deemed necessary.

C. Curriculum Based on Research and Development Options Within a Professional Program

In order to provide special programs scientifically oriented for students interested in research, development, teaching, and creative design, a special sequence of courses can be arranged within a given program of study such as in electrical engineering. Programs of this type generally start at the sophomore level and continue on through the senior year. Students in these programs are usually encouraged to continue their educational program by taking graduate work.

D. Design of Programs Based on Bifurcation by Scientific and Professional Stems of Engineering Within Professional Engineering Areas

Due to the variation in interests of students, some engineering educators advocate the design of bifurcated programs within a given professional area; for example, mechanical engineering. In these arrangements students interested in research, development, teaching, and creative design, follow a program which contains courses of study oriented toward the physical sciences and the engineering sciences. The other stem is built on a strong foundation of the physical and engineering sciences but has built-in flexibility to allow students to take courses in present-day practice, management, and other less scientific subjects. Although it is not possible to clearly classify these programs as such, one leads to the education of students who are interested in solving the problems of tomorrow, while the other is equipped to solve the problems of today. Both types of engineers are extremely important in the continued development of our industrial complex.

E. Design of Programs Based on Functions Performed by Engineers

As a result of the great variability of interest of students and the many different functions performed by engineers, some engineering educators feel that a suitable curriculum should consist of a common three-year program based on the physical and engineering sciences, followed by a year wherein the student elects options according to functions. For example, options consisting of well co-ordinated courses would cover such areas as construction, instrumentation and testing, technical sales, systems maintenance, and manufacturing.

Other procedures may be evolved which utilize combinations of those presented above.

VII. Course Planning

Many factors must be taken into consideration in the detailed planning of the courses covering subject matter areas, some of these are:

A. Time devoted to course.

B. Structure of the course.

This involves establishing a lecture or laboratory course or combination of lectures, recitations, and laboratory.

C. Preparation of the students.

The preparation of the students is usually specified by prerequisite work or courses which the student must have before enrolling for a specific course.

D. Background of the teachers.

E. Detailed requirements.

The detailed requirements involve tests, home problems, recitation periods, etc.

F. Available reference books, texts, etc.

G. Student enrollment expected in the course.

H. Scholarly level of presentation of the subject matter.

VIII. Conclusions

It becomes obvious after a study of course and curriculum planning in the various engineering schools in the United States, that there is no one solution for all schools. Much depends upon the type of student body, faculty, and facilities. Each school should design the program of study to best fit its needs, and at the same time assure its students the opportunity of developing so as to be able to compete with his counterparts from other schools.

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INSTRUCTIONAL PLANNING

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I Introduction

Instructional planning is concerned with the organization of a course of instruction and the individual class or laboratory lessons in accordance with whatever curriculum and course planning has preceeded it. It is that part of the work carried on by the instructor with the objective in mind of developing proper lesson plans and the selection of the best testing and evaluation procedures for the particular course.

Instructional planning is similar to any other type of planning: it takes time and thought coupled with hard work and attention to details. It cannot be approached casually or done hurriedly (while the class is in session, for example) like the planning that goes on during an extemporaneous speech. If it is, the results are apt to be just as casual. The Engineering teacher in particular should be able to apply the same careful type of analysis to the problems of instructional and lesson planning that he would apply to the solution of any other problem. He must aim for maximum--not minimum--results. As in all engineering problems, efficiency is paramount and this depends on a clear plan or a complete set of blue prints.

It is not the purpose of this paper, however, to lay down a rigid outline for any particular subject, but rather to review and benefit from the experience and writings of others so that the necessary principles for sound instructional planning may be summarized and listed in logical order for easy application.

II Elements of Instructional Planning

Instructional planning plus the lesson presentation make up the complete instructional process. Its objective is an adequate and effective presentation to the class; its goal, effective teaching for effective learning. Whether teaching has occurred and learning resulted will be determined in the examination and evaluation phase. The complete process can be broken down into a total of four main phases or work areas; namely, preparation, presentation, examination and evaluation, and critique and improvement.

A Preparation

The preparation phase is by far the most important because all the others depend upon it, and planning is the key to its success. A sound plan is a principle of sound organization, and instructional planning involves organization. Other principles that will result in the production of a good plan, when applied carefully, are expressed in a simplified or systematic arrangement of whatever facts, procedures or materials the project requires. The work of the preparation phase can be subdivided for better organization and checking into divisions like the ones below.

1. Estimate of the situation (course or problem). This would be made on the basis of the prepared course outline. Figure I is an example of a sample course outline[1] similar to what the instructor might be handed to guide him in his planning. Circumstances other than the mere issuance of a prepared course outline may dictate the organization of a course and the subsequent lesson planning. The instructor himself may have seen the need or desire to offer the material, or he may be taking over from someone else who has previously taught the course with the purpose in mind of adding to or updating the material. In any event, it is assumed that the objectives of the course have been clearly and definitely stated by those responsible for the inclusion of the course in the curriculum, and that the instructor has a clear conception of these objectives. The instructor will then be in a position to review the objectives and scope of the course and the goals to be attained. After which he can proceed to analyze the subject for presentation.

The estimate of the situation should also include a review of the background of the students, the course prerequisites and the intelligence level of the class. There is seldom sufficient time to carry this out, but individuals and classes have varying amounts of ability and interest and it is highly desirable to know the class.

A review of the physical facilities needed and/or available will be necessary. This is obvious in the case of a laboratory, but is frequently neglected for other types of presentations.

The same is true for teaching aids. The instructor may have to plan around what is available, rather than what he wants or complete this part of his planning sufficiently far ahead so that the teaching aid can be purchased (if money is available) or constructed.

The time allotment should be given careful attention to assure each topic, including quizzes and tests, its proper proportion of the total time available. It may be wise to provide some flexibility and allow a little slack in the system to provide for unexpected surprises, like an epidemic, athletic holiday or ice storm.

The method of instruction may be dictated by the course outline, but frequently the instructor will have some choice between a lecture or conference type of presentation, for example. It may even be desirable to use several different styles, depending on the individual lesson topic or as a means of experimenting for effectiveness.

The method of testing and evaluation that is best suited to the particular course should also be given some thought during the estimate of the situation and chosen carefully.

2. Research and accumulation of all necessary background material. It may be necessary, as a result of the estimate of the situation, to secure additional information through experimentation or library research. This is in the manner of acquiring as thorough and comprehensive a knowledge of the subject as possible.

3. Organization of the material. This was probably started along with the estimate of the situation, but it is an important step in our planning. The instructor must begin to select and sort his material with a view to the specific objectives and complete coverage. Some kind of a logical and sequential order must be used; such as, known to unknown, simple to complex, easy to difficult.

Proper organization will also include the selection of the most effective teaching aids, references, and problems for either quizzes or home work. Homework assignments must be planned carefully, problems worked thoroughly and stated clearly.

4. Preparation of lesson plans. The development of proper lesson plans was pointed out as one of the main objectives of the broader topic of instructional planning.

a. Definition. A lesson plan (see Figs. II and III) is a guide to the presentation of an individual lecture or lesson. It includes an outline of the scope of the material and of the procedures the instructor intends to follow in presenting a lesson. All of the other phases of the teaching and learning process culminate here in proper order for the most effective class presentation.

Care must be taken to include all of the important facts in the outline so that the element of memory (frequently fickle in times of stress) is reduced to a minimum. No point which is sufficiently important to require detailed explanation during the lesson development should be omitted from the outline. More elaborate instructions can be filled in by the instructor according to his own needs, but they should be incorporated in the plan as they are noted in the outline.

b. Functions. The lesson plan or outline can assist the instructor and give him support in the preparation of the lesson and during the presentation. This support is most evident and helpful as: a guide to the preparation of the lesson; a guide to the physical arrangements and facilities, either needed or available; a confidence builder, and an assurance of uniformity and continuity throughout the course or series of courses.

1) Preparation of the individual class lesson. In this area the lesson plan provides a check sheet for that infinite number of factors which can strengthen or weaken the lesson, many of which must be considered in the preparatory phase: Subject coverage, method of teaching (lecture, recitation, etc.), location of classroom, visual aids needed, or assistants needed, to mention a few. Better to give them some thought in the preparation than to have them come up unexpectedly during the lesson and cause confusion and embarrassment.

2) Physical facilities. Give ample thought to the physical facilities such as equipment and arrangement of classroom, including lighting, ventilation, and all other factors that contribute physically to the development of the lesson. The ridiculous little detail of having chalk and erasers available, for example, is often a nuisance. These are simple administrative details that are the responsibility of the instructor, but which too often he considers beneath his dignity. They do contribute to the well being and general smoothness of the presentation.

3) Confidence builder. Again proper planning will assure a proper and complete outline of each lesson. The instructor will usually rely heavily on his lesson plan or outline the first few times he teaches a course. He must guard against a false sense of security during subsequent sessions or he may find himself distracted or sidetracked (by irrelevant questions or remarks that must nevertheless be

answered) and experiencing difficulty in picking up the thread at the correct point again. He may even find himself being drawn ahead more rapidly than is desirable. If his memory fails him at such critical times, the presence of the lesson outline represents a real crutch or confidence restorer. Students have an uncanny knack for confusing the issue and how many times has the instructor thanked his "lucky stars" that his notes clearly indicated the next step so he could regain his composure.

4) Uniformity and continuity. The course or lesson plan provides continuity regardless of who may teach the course or lesson. It can provide uniformity of coverage when more than one instructor is teaching the same course, as is often the case in subjects like Mechanics, Thermodynamics, or Fluid Mechanics. It assures that the objectives and subject matter will be uniform between different instructors' classes without in any way restricting the techniques or methods employed by the individuals. Thus, they have an opportunity to fill in the framework in their own unique way. This creates interest and offers an opportunity to study the effectiveness of individuals or techniques.

c. The Lesson Outline. (See Figure II). Much of the detail work and the research will have to be completed before the actual outline of the individual lesson is started. Most instructors have probably developed some sort of format that they prefer or which they have become familiar with. The particular form is not important except that is should be clear and concise and arranged in some logical order. The outline will also depend on the type of class being planned for and the method of presentation.

Regardless of the type of lesson, however, the plan will probably fit into an outline including the following main divisions: heading, introduction, development or discussion, and summary.

1) Heading

The heading will normally include the miscellaneous administrative details, such as the course name and number, subject heading, title or subtitle of the particular lesson, time allowed, type of lesson, place, teaching aids needed, and assistants. It can also provide a location for the noting of other items of interest, like a statement of the objectives, the references and reading and/or problem assignments.

2) Introduction

The introduction serves a number of purposes, which will also depend on the type of lesson. In general, it reviews what has gone before and points up what will be accomplished in the particular lesson. It serves a connecting link or tie-in with the previous lessons to help attain the continuity mentioned earlier, and to jog the student's memory on the important points in previous lessons that may have a bearing on this one.

It provides an appropriate time to state the objectives so that the student's interest may be aroused immediately and some anticipation for what is coming realized. Developing interest and anticipation at the start of the class can improve the atmosphere in which the learning process takes place. It also helps to focus the student's attention on the immediate problem or lesson. An attention getter can be a motivator.

Something must be done, of course, to retain the student's initial interest throughout the lesson. A clear statement of the purpose of the lesson, where it fits into the course and the course into the curriculum may be sufficient and necessary.

3) Development

With the foundation laid and the framework started the instructor can begin the development of the main part of the lesson.

In this section the outline must present the main and subtopics in logical and sequential order in conformity with the scope and objectives previously established. Proper attention must be paid to the time allowances for each topic and the teaching or visual aids required. References mentioned should be available and carry some note concerning their usefulness.

Certainly a "thorough and comprehensive" knowledge of the subject matter is necessary to accomplish the above. The instructor must guard against overestimating the ability of the students to grasp a given topic in a given length of time. The review of the student's background, mentioned earlier, is also of value here.

The attention to detail in this part of the outline is most important. It should be as complete as possible, and indicate probably quizzing or questioning points, the places where teaching aids are to be brought in, where models or diagrams are to be used, et cetera. Figure II is an example of a very detailed Instructor's Lesson Plan and including an Outline for a lecture demonstration type of lesson. All of the basic elements discussed in this paper are included in the plan and the distinction between the lesson plan and the lesson outline is clearly illustrated. Obviously, the older, more experienced instructor will not require this much written detail, but it would be better for the young instructor to have too much, rather than not enough.

It should provide for some flexibility and allow a little slack in the lesson to account for unexpected surprises here, too. For example, if the class moves more rapidly and more smoothly than anticipated, a place can be provided to expand the discussion or insert an extra problem example.

4) Summary

This is the last main division in the lesson outline and serves a number of very important functions. Primarily, it provides an opportunity to review the important points and to tie in the lesson with the next one in line.

Review is a stimulus to "recall" and the instructor can take advantage of this psychological fact to fix the important points of the lesson in the student's mind. The summary can thus be an important teaching tool. Review can be accomplished by the lecture method or by questioning the students. The latter method has the advantage of providing the instructor with a measure of his own effectiveness and/or the students' alertness.

Tying-in the lesson with the one to follow can be a strong interest creator and motivator and will help to retain the continuity of the course. The proper treatment of reading and study assignments as well as homework can be a strong factor in motivation. If the instructor treats this point casually, the student may have a tendency to do the same thing.

d. Tests and Quizzes. Examinations, or the planning therof, are an integral part of course planning. A complete course outline will probably indicate the most likely quizzing points, but it will be up to the instructional planner to fit them into the course properly. The philosophy of testing and evaluation is a part of the principles of teaching and learning, but the examinations will have to be planned to accomplish the purpose at hand or the objectives of the course. Quizzes should normally be given at points of continuity breaks between topics and normally should not require more than about five per cent of the total class time.

Problems, both homework and test problems, should be comprehensive and pointed to a purpose, not just busy work. However, the student needs to be made to understand that there is some drudgery attached to any job. It cannot all be high and lofty.

Testing can be another form of self-evaluation for the instructor; it can measure his effectiveness and helps uncover difficulties and thus suggest where remedial action is necessary.

5. Dry run. Review the lesson plans and outline thoroughly. Do not hesitate to rehearse the procedures and the presentation. Seek aid and counsel from older staff members. This may sound idealistic, but it is most important. Unfortunately, time is seldom available for this function.

6. Critique and revision. Further, do not hesitate to revise the plan and outline in accordance with the dry run or advice from others.

B Presentation

As noted previously, this is not strictly a part of instructional planning, but does complete the instructional process. We include it for this purpose--completeness--and also for the part it plays as a review for subsequent offerings of the same lesson. For purpose of discussion, the presentation phase can be considered in three subphases: the pre-class period, the class period and the post-class period.

1. The pre-class period. Whether this occurs the day before or the hour before the lesson, it should include a review of the outline (or notes), a check of the physical facilities and teaching aids, (is the projector available and working, do the lights work, are chalk and erasers available?), a moment to look in the mirror, and a noment to regain one's composure and sense of humor. Remember that the teaching aids appeal to more than one sense--sight, sound, and maybe touch--they encourage alertness and promote interest. When working properly they can be a big help during the class period. The instructor's appearance and attitude can be either beneficial or detrimental to the student's receptiveness. The instructor is supposed to be a teaching aid, too. He should be seen, heard and understood, but not offensive.

2. The class period. All the previous planning is focused here. After the instructor has established contact with and sized up his class,

he must secure their attention and create the interest necessary to carry them through the period of the lesson. Here the lesson plan and outline begin to function. The importance of the planning, the preparation and the lesson outline is now all to obvious to both student and instructor. A lack of these elements can also be obvious and embarrassing.

3. The post-class period. This is the time to review the presentation and the material coverage and to make notes for the next lesson or future offerings of the same lesson.

No instructor and no lesson plan is perfect or perfect enough to meet all future situations, regardless of the amount of time spent on the original planning. Therefore, some time must be provided to review the lesson and a place provided in the outline to make notes for future reference. The most appropriate time for this is immediately after the class session when the strong and weak spots will be vividly in the instructor's mind.

C Examination and Evaluation

This third phase of the instructional process is a direct part of the planning. Time must be provided for it and thought given to it. It has been discussed previously where it logically fitted into lesson planning and the details and philosophy have been discussed in detail by many authorities. Suffice to say here that it serves to measure student learning and teaching effectiveness by revealing the strong and weak points of the instruction, to stimulate review, and to provide motivation. The announcement of a quiz can be an attention getter, an interest arouser and a strong motivator for study.

D Critique and Improvement

This fourth and final phase of the instructional process is also a direct part of instructional planning. It has been discussed above in the section on preparation in connection with its relation to lesson planning and the lesson outline.

Here, however, we look at it in the light of the complete term's work with the entire course as a background. We can review the coverage, the evaluation and testing techniques, the time allotted to the various topics and subtopics and seek the aid and counsel of our colleagues through discussions with them.

If the course has been taught by more than one instructor, the course supervisor may wish to conduct a more formal type of review.

In any event, notes and changes should be made where indicated and as soon as possible after the completion of the course.

III Summary

In summary, Instructional Planning is a most important part of the instructional process; it takes up where course planning leaves off and carries through the lesson planning to the review of the course as presented. It forms the bridge between the wealth of material that is available on a given subject and the portion learned and retained by the student for use, as well as his attitude toward it.

It includes and depends upon a thorough knowledge of the subject and involves the necessary research and counselling to present it to the student in the most effective manner.

It involves thinking through the total problem of the lesson and then making a careful selection of the material available with a view to the specific objectives.

It includes the outline for the course with the objectives clearly stated and the detailed outlines for each day's lesson expanded in a manner or form somewhat as follows:

- A. Heading
    - 1. Administrative details
    - 2. General announcements
    - 3. Course mechanics (teaching aids needed, assistants, etc.)
- B. Introduction
    - 1. Review--tie-in with previous lesson
    - 2. Historical remarks
    - 3. Objective and course of action
- C. Development or Discussion
    - 1. Main body of material
    - 2. Subtopics
    - 3. Question and answer period
    - 4. Use of illustrative problems
    - 5. Use of visual aids

D. Summary
    1. Summary of main points
    2. Assignments--reading or problem

E. Notes and revisions
    1. Self-critique of coverage, attitudes, impressions and accomplishments
    2. Notes for future classes

From an engineering viewpoint the instructional process could be likened to the development and construction of a bridge, skyscraper or missile. In all cases the planner must recognize his goals and objectives, think through the total problem, lay out his plans carefully, work out the administrative details, establish a foundation (motivate and create interest), construct a framework (indicate the plan of attack, path, or particular slant that the lesson will take), fill in the main body of the structure (present the basic background and working knowledge that we want the students to learn and retain to use), enclose it in an attractive outer shell (apply our psychology, teaching aids, demonstrations, et cetera), and cap it off with a roof to protect the insides from the elements (review and evaluate through some sort of testing method so what we have presented will not be lost, destroyed or damaged), and thus accomplish his goals and objectives.

In instructional planning the framework can and probably will take on different forms depending on: 1. The material to be presented, whether fundamental laws or basic concepts, techniques or the development of them, skills or a combination of these; 2. The manner in which the material is presented, whether lecture, conference, recitation, problem session, seminar, or laboratory; and 3. The manner of evaluating the accomplishment, by finals, quizzes, reports, home problems, or combinations of them.

The type of roof used will, undoubtedly, also depend on the manner of presentation, the contents (material presented) and the outside environment (intellectual, cultural, or void).

FIGURE I

SAMPLE COURSE OUTLINE[1]

THERMODYNAMICS: M. E. 328

Revised__________, 19_____

Suggested Text_______________

Time Allowance

1. Five contact hours per week, ten weeks plus final exam.
2. Ten hours of required study per week.

(Assignments should be limited to what can be done satisfactorily in this time in accordance with the academic standards of the school.)

Course Objectives

1. The main objective of this course is to introduce the student to the field of thermodynamics and to develop an understanding of the properties of gases, the properties of gaseous mixtures, the basic principles of gas processes, and the first and second laws of thermodynamics.
2. The student will be expected to achieve a mastery of the subject material specified such that he will have an elementary understanding of the first and second laws, will be able to solve ordinary problems involving gases, and will have some facility in the solution of problems involving the application of the gas laws to various types of machines using gases.

General

1. The subjects listed below are prescribed; the order of presentation is suggested.
2. The suggested time allowance for subjects is given in parentheses to indicate the relative emphasis or extent of treatment to be given during class hours.
3. The degree of mastery in the available time is predicted upon the effective use of the suggested references and aids.

Course Content	Suggested Time Allowance in Hours
1. The First Law of Thermodynamics, the General Energy Equation and its application: References____________________________	(6)

2. Properties of the perfect gas; the characteristic equation: (6)
   References ______________________
   Aids ______________________

3. Energy relations of a perfect gas: (11)
   References ______________________
   Aids ______________________

4. Test (1)

5. (A continuation of subjects as required)

6. ______________________

7. ______________________ (26)

50

FIGURE II

U. S. ARMY ENGINEER SCHOOL FORT BELVOIR VIRGINIA

INSTRUCTOR'S LESSON PLAN[2] IG.003-1

SUBJECT: Gasoline Engines FILE NO. M-005-6

TITLE OF LESSON: Ignition System COURSE: Engine Repair

TIME: 50 minutes ASSISTANTS: 2

TYPE OF LESSON: Lecture UNIFORM: Class "A"

PLACE: Classroom

AIDS: Blackboard, Model Distributor, Coil Charts, Model Circuits

OBJECTIVE: To teach the component parts and operation of the ignition system on a gasoline engine.

INSTRUCTOR REFERENCES: TM 9-2700, pars 73-75, Delco Remy Training Chart Booklet

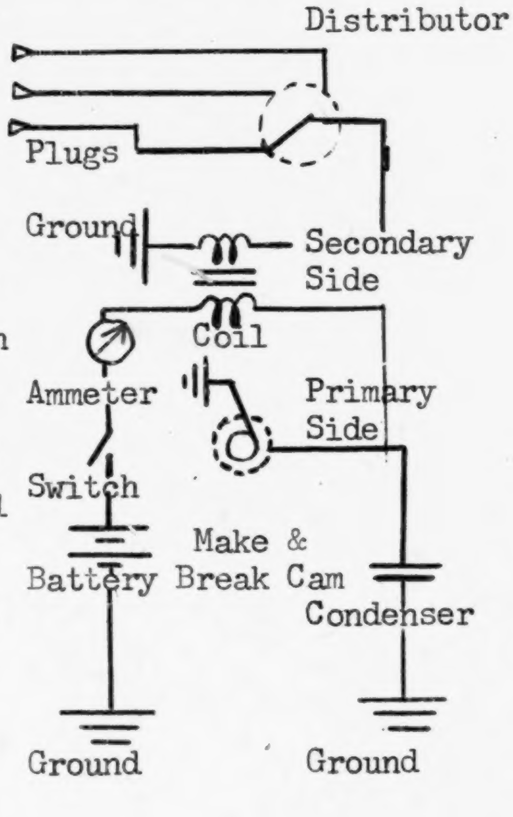
STUDENT REFERENCES: TM 9-2700, pars 73-75, Power Primer pp 440-48

TIME LESSON OUTLINE KEY POINTS & TNG AIDS

INTRODUCTION

0000 (Story - What happened in North Africa due to improper operation of gasoline engines). This story clearly illustrates what can happen when knowledge about gasoline engines is lacking in a military unit. Since you are already familiar with the operation of fuel and cooling systems in a gasoline engine, we will now discuss the operation of the ignition system on a gasoline engine. This knowledge will help you in preventing incidents such as those mentioned in the story above and it will help you to more effectively deal with any problem arising in the ignition system of any gasoline engine.

Draw diagram on blackboard progressively



0003 DEVELOPMENT

1. Parts of the system
   a. Primary circuit
   b. Secondary circuit

FIGURE II (con'd)

TIME	LESSON OUTLINE	KEY POINTS & TNG AIDS
0003	DEVELOPMENT (con'd)	
	2. Primary circuit	
	a. Battery	
	(1) Construction	
	(2) Electrolyte	
	(3) Principle of operation	
0018	b. Switch	
	(1) Types	
	(2) Function	
	c. Coil	
	(1) Construction (Expose chart)	
	(a) Primary winding	
	(b) Secondary winding	
	(2) Operation (Remove chart)	
0025	d. Cam and breaker points	
	(1) Location	
	(2) Nomenclature	
	(3) Functions	
	e. Condenser	
	(1) Construction	Demonstrate with model of distributor
	(2) Operation	
0035	3. Secondary circuit	
	a. Distributor	
	(1) Parts	
	(2) Function	
	(3) Timing	
	b. Spark plugs	
	(1) Nomenclature	Demonstrate operation of both circuits w/model
	(2) Functions	
0040	4. Operation of both circuits (complete)	
	(Questions and Comments Period)	
0045	SUMMARY	
	1. Primary Circuit	
	2. Secondary Circuit	Refer to drawing on blackboard
	3. Introduce next lesson on care and maintenance of ignition system.	

FIGURE III

SAMPLE LESSON PLAN[3]

Department______________________________Instructor____________

Course__________________________Lesson No.______Date___________

Specific Objective____

Instructional Aids____

MAIN TOPICS SUB-TOPICS

Interest Stimulator____

Presentation____

Application____

Quiz____

Text Assignment____

Problem Assignment____

Reference Assignment____

Announcements____

Remarks on Class Session_______________________________________

FIGURE IV

SAMPLE LESSON PLAN[7]

(Use of the Guided Discussion in Teaching)

LESSON TITLE:	Principles Useful in Effective Learning
UNIT TITLE:	Nature of Learning
COURSE:	Academic Instructor Course
INSTRUCTOR:	Lt. John T. Snow
ADVISER:	Maj. L. T. Murphy

Part I. Overview

LESSON OBJECTIVE: The objective of this lesson is for each student to understand some of the important needs and principles which influence learning.

DESIRED LEARNING OUTCOMES: Each student should--

1. Realize that learning must effect some change in the behavior of an individual.
2. Understand the personal-social needs which must be recognized in the learning process.
3. Understand that goals should be set up by the instructor to satisfy personal-social needs.
4. Understand that such principles of learning as readiness, frequency, and association can be used to enhance the learning process.

INSTRUCTOR REFERENCES:

1. Burton, William H., The Guidance of Learning Activities, 2d ed., New York, Appleton-Century Crofts, Inc., 1952.

2. Davis, Robert A., Psychology of Learning, New York, McGraw-Hill Book Co., 1935, pp 93-126.

3. Mort, Paul R. and Vincent, William S. Modern Educational Practice, New York, McGraw-Hill Book Co., 1950, pp 401-407.

4. Witherington, H. Carl, Educational Psychology (Rev.), Boston, Ginn & Co., 1952, pp. 163-194.

5. Mursell, James L., Psychology for Modern Education, New York, W. W. Norton & Co., 1952, pp 32-93.

INSTRUCTIONAL AIDS: None
STUDENT PREPARATION: None
HANDOUT MATERIAL: None
TIME REQUIRED: 35 minutes

PLAN OF PRESENTATION: The instructor will introduce the lesson by making clear to the students the specific areas to be discussed. He will then ask the group to discuss how learning can be recognized. After the students have arrived at a common understanding of basic concepts, they will be guided into the lesson by questions which will bring out the personal-social needs behind learning. The instructor will control the discussion by setting up problem situations and then asking key questions to develop the desired learning outcomes. This procedure will also be followed in bringing out pertinent information related to some of the principles of learning. The lesson will close with a brief summary of the conclusions reached by the group.

Part II. Teaching Guide

Student Outcomes	Student Activity	Instructor Activity
	A. INTRODUCTION (5 Min)	
Understand the importance of recognizing needs which motivate students.	Listens and makes a mental note of the objective for the lesson.	Briefly indicates the scope of the hour by explaining that the needs of the students must be considered in the learning process. Also explains that this discussion will be concerned only with the personal-social needs and some of the principles of learning which may be used to satisfy these needs.
	B. DEVELOPMENT (25 min)	
1. Understand that learning must effect some change in the behavior of an individual.	1. Anticipated responses: a. Mental growth increases. b. React differently.	1. Asks: Can anyone tell me what happens to a person when he learns something?
2. Understand that many needs arise from personal-social pressure.	2. Anticipated responses: a. Gain a sense of conformity. b. Gain a sense of belonging.	2. Asks: If you feel the need to buy a television set just because the neighbors are doing so, what needs are you trying to satisfy?
3. Understand the need to recognize the personal-social needs in the learning process.	3. Anticipated responses: a. New experience. b. Security. c. Self-esteem. d. Need to help others.	3. Asks: What are some other needs that motivate people to do things?

Student Outcomes	Student Activity	Instructor Activity
4. Understand that goals should be set up by the instructor to satisfy personal-social needs.	4. Anticipated response a. By preventing situations that lead to frustration. b. By planning goals that will recognize these needs. c. By setting up purposeful activities to satisfy the needs identified.	4. Asks: How can instructors improve their teaching by identifying the personal-social needs of students? (Summarize discussion to this point.)
5. Realize that certain principles of learning should be applied after the students have been motivated.	5. Listens	5. Explains the importance of understanding some of the principles of learning in guiding students toward satisfying recognized needs. (Takes, in order, as many discussion topics as time permits concerning principles of readiness, frequency, association, and effect.)
6. Understand the importance of preparing people to learn.	6. Anticipated response a. Indifference b. Failure to prepare c. Lack of confidence in instructor. d. Disappointment.	6. Asks: What attitude would an instructor create by constantly making assignments and then failing to follow up with appropriate student activity?
7. Realize that students are ready to learn only when a need is recognized.	7. Get the student ready for classwork.	7. Asks: What did the instructor have in mind when he first made the assignment? Tells students that this is called the principle of readiness.
8. Understand that repetitions are worthwhile but must be properly spaced.	8. Anticipated response a. Repetition is necessary. b. Important concepts can be lost in details. c. Every idea has many applications.	8. Asks: Why would the rule of "Tell them once and expect them to remember" be a bad one to follow? Tells students that this involves the principle of frequency.

Student Outcomes	Student Activity	Instructor Activity
9. Understand that the more associations which can be made, the greater the possibility of understanding and retention.	9. Anticipated response: a. Tie-ins are valuable. b. Helps with transition. c. We should show relationships. d. New material should grow out of old. e. Continuity is established.	9. Asks: Why is a brief summary of the highlights of the preceding hour worthwhile? Tells students that this involves the principle of association.
10. Understand that the principles of learning must be considered in every classroom situation.	10. Anticipated response: a. In planning for motivation. b. By reviewing of previous material. c. By keeping related material close together. d. By setting up achievable outcomes.	10. Asks: How can an instructor use these principles to make learning more effective for his students?
	C. CONCLUSION (5 min)	
1. Understand that the personal-social needs can be recognized and used in applying the principles of learning.	1. Listens, recalls, and accepts conclusions.	1. Summarizes student contributions in terms of desired learning outcomes. Ties these in with desired learning outcomes that were achieved and states those which were not achieved.

REFERENCES

1. Instruction Manual: An Aid to Effective Instruction. Georgia School of Technology. Third Edition. Atlanta: Georgia Institute of Technology, Department of Public Relations, 1957.

2. Effective Instruction. Instructor's Guide, Parts .003-1 (4-58), .003-2 (2-58), .003-3, .005-3. Fort Belvoir, Virginia: U. S. Army Engineer School, Instructional Methods Branch Training Division, 1958.

3. Morris, Fred C. Effective Teaching: A Manual for Engineering Instructors. New York: McGraw-Hill Book Co., Inc., 1950.

4. You and Your Students. Prepared by a Faculty Committee under the chairmanship of Professor Robley D. Evans. Massachusetts Institute of Technology, Office of Publications. Boston: The Rand Press, 1959.

5. "Improvement of Engineering Teaching". Report of the Committee on Improvement of Teaching. Journal of Engineering Education, Vol. 43, No. 1, September, 1952.

6. Instructor's Manual. Parts .003-1, .003-2, .003-3, .005-1. Fort Belvoir, Virginia: U. S. Army Engineer School, Instructional Methods Branch, n.d.

7. Principles and Methods of Instruction. Academic Instructor School, Air University. AIS-2. Maxwell Air Force Base, Alabama. April, 1960.

THE PLANNING OF INSTRUCTIONAL ACTIVITIES

H. T. Morse
University of Minnesota

Those who are fond of citing Chinese proverbs may say cheerily to one facing a monumental task: "There is an old Chinese proverb which says, 'A journey of a thousand miles begins with but a single step'." We must admit that this is obviously true, though perhaps not very heartening. We might possibly propose on further reflection that our proverb-citer might add to this ancient wisdom..."and in the right direction."

It may not be pressing the analogy too far, I trust, to suggest that the planning of instructional activities on the part of the teacher is this first inescapable step "in the right direction" toward a journey which may seem long, but which need not be tedious. In some circles, however, a form of academic folklore is current which holds that attention given to planning classroom activities is time spent wandering on the "educational wastelands", and that the teacher worthy of his salt will do the necessary things, prompted and guided by a fine intuition or instinct for properly achieving the good, the beautiful and the true. This is a pleasant illusion indeed, and a comforting one in that the dreamer has a rationale for not exercising his mental faculties to this end. But serious students of college level instruction have offered convincing documentation that the lack of planning is all-too evident in the aimless wanderings in many observed class sessions, which stand in sharp and deplorable contrast to well defined activities which show careful planning and orderly progression toward well-defined goals.

Those who cling to the comfort of belief in intuitive planning and operation often justify their position by scorning "lesson planning" as "high school stuff", and may allude to anecdotes on the subject which may be intriguing, but perhaps apocryphal. There are extremes of any practice, it must be freely admitted. And in presenting a case for conscious planning, I am by no means advocating the detailed "daily lesson plan" which bedevils the life of many a teacher at the elementary and secondary levels.

Possibly the most extreme case of hide-bound "lesson planning" in its most limited and bureaucratic form is the proud remark attributed to Monsieur So and So, Minister of Education in France in the early years of the current century, who is reported to have pulled out his watch one morning, and to have said to an official visitor, "It is now exactly twenty-seven minutes to eleven a.m. By referral to my planning table, I can tell you exactly what page of what book every seventh-grade school child in France is studying this very minute!"

But we are here a long ways removed, geographically and chronologically, from the France of the beleaguered seventh grader of 1907, or any other grader locked into that grand design. And it is to be hoped also that we are also a long ways removed idealogically from Monsieur the Minister of Education, with his gold-chained watch and his infallible time table.

It would be superfluous indeed to propose to persons trained in engineering that if a product is to be engineered or produced, blue prints will need to be prepared as an initial phase. Ours is an industrial civilization, and it is natural even to one who has only the vaguest notion of industrial processes to think in terms of "blue print to assembly line". In college teaching we are also processing young people, in a sense, although the assembly-line analogy leaves much to be desired, despite the gloomy mutterings in some places about "mass education". But the analogy holds up surely to this extent--In every phase of the educational process, if it is to be conducted with efficiency, there must be conscious planning toward desired ends. There must be careful planning of the total collegiate program, whether it be liberal arts, professional, or specialized. There must be careful planning of all the elements and stages--the specific curriculum, the individual course, the topic to be covered and the means of covering it, the special aids to be used, if any, the adaptations to the nature of those being taught, and finally, but certainly not the least important, evaluation of the outcomes of learning to determine the extent to which teaching and learning have been proceeding at the appropriate levels and with the necessary intensity.

The image of the assembly line, a concept familiar even to a boy in the fifth grade, connotes a number of things, and among them precision and uniformity. Our schools and colleges, some critics aver, pattern themselves too much in this image, and tend to emphasize conformity and standardization at the expense of individuality and creativeness. They point to grade-levels into which students are divided, norms, "minimum essentials," standardized examinations, uniform assignments. There is undoubtedly much in this situation to stultify the imaginative and corral the academic maverick, but much of this machinery and these attributes are useful if they become means to an end and not the end itself.

VARIABLES IN THE TEACHING PROCESS

It may jar our stereotypes a bit to suggest that the really effective college teacher is dealing with variables rather than constants in conducting the educational enterprise. In actual fact, the more skillful the instructor, the greater will be the variations in achievement among the students under his care. Why should this be so? For an answer, let us turn to a consideration of the various elements involved in the teaching-learning process at the college level. Although these may be variously classified, for our present purpose we may divide them into four categories: (1) the total program of which a particular course is a part, (2) the subject matter content of the course itself, (3) the physical setting in which the teaching and the learning take place, and (4) the nature of the learners.

It might be proposed, with some justification, that what is perhaps the most important single element in the whole situation or process is not listed above, and this is the individual classroom teacher himself. One with an easy-flowing pen might make the most of such a variable. He might present our instructor as a crusty veteran of many an academic encounter, hardened to the foibles of intransigeant youth, hewing to the line, and letting the chips (and the chaps) fall where they may. He might be pictured as a young man, eager but uncertain, feeling his way cautiously into this new experience, putting on a bold front to hide his real or imagined inadequacies, fearful lest a student, in jest or ernest, ask him a question about his subject the answer to which he should know, but which he doesn't, and fearful too to admit this shortcoming, convinced that an instructor should never be trapped into the admission of not knowing all the answers. Or he may be a young man trained as an electrical engineer who has been required to teach elementary sections of math and mechanics, so that he takes somewhat less than a charitable view of his assignment, his superiors, his associates, his students, and the world in general. Or perhaps his mother-in-law is visiting him, or perhaps he has had some other argument with his wife that morning, and the cream was sour at breakfast time to boot, or perhaps he stayed up too late last night, or perhaps the Graduate School is still being unreasonable about the courses on his degree program, or he can't find a thesis topic, and his advisor is no help, deliberately perhaps, or so it seems.

Here are variables indeed, and if these were extended, as well they might be, there would seem little time or opportunity to examine the other components. But we must have some premises to begin. And so for the sake of argument we will assume, in discussing instructional planning, that our instructor of engineering subjects is young, well motivated, eager to learn how to become more efficient, open-minded, professionally dedicated, fair and humane, and genuinely interested in having his students make the most of their opportunity to learn.

An Overview of the Curriculum

It may seem inappropriate in a discussion of planning specific classroom activities to raise any point about the total program of which a particular course is an integral part, particularly in view of the fact that other portions of the Institute program are devoted to broader phases of course and curriculum planning. But we may recall some of the syllogisms in our first course in logic or the circles diagrammed on the page of our tenth-grade geometry book, in which it was solemnly alleged that "all B is A, et cetera, et cetera, Q. E. D." That is to say, if a given course occupies a place in a sequence or in a whole curriculum, whether it be mechanical, chemical, electrical, mining, or what have you, the impact on the given course of the rest of the program must be taken into account in the intelligent planning of course and individual class session activities. The instructor, like the two-faced Roman god Janus, must look both backward, to see what has gone before, and forward, to see what is ahead. Such scrutiny should surely allow him to consider thoughtfully how the particular segment for which he is responsible will most satisfactorily fit into the total pattern of his students' learning experiences.

An overview of contemporary trends in higher education in this country reveals, among other things, that the amount to be learned in preparation for active employment in any professional field has become so great that there has been an increasing tendency to lengthen the period of training. The field of medicine is probably a prime example. As relatively short a time as two centuries ago, there was little systematic formal preparation for the practice of medicine. Young men who wished to follow this "profession" (one practiced by barbers in an earlier period) got what formal education they could manage or afford, none of which was in the so-called basic sciences, which were not yet an organized or respectable field of study, and then apprenticed themselves to an established physician and got what we now refer to as "on the job training". Under these conditions, even allowing for the helpful ministrations of many wise and experienced men, the term medical "practice" was probably no mere accident of semantics. Not only medicine, we are all aware, but other occupational fields, including engineering, required a more and more extended schooling to master as time went on.

Because fields of learning, with the expansion of knowledge, became fragmented and highly specialized, a counterbalancing force was set in motion to broaden the professional curriculum, as well as to lengthen it. Thus we have the advent of the general education movement, which was designed to provide a common base of learning and a perspective on man and his relations to his physical, social, and cultural world. Many professional programs, engineering among them, began to require prospective practitioners to take courses in general education as a supplement to their technical training. Courses devised and used for this purpose were often the integrated courses frequently called "Natural Science", "Social Science", and Humanities".

Our planner of classroom activities in an engineering subject must be aware of all this if he is to do his immediate job with maximum effectiveness. Ideally, he must be able to capitalize on the learning experiences his students have had up to the time they enter his course, and in that course to prepare them adequately for the further learning experiences which lie ahead of them.

The Content of Individual Courses

To a lesser degree, the same principle of perspective would apply to the second element of the teaching-learning process--the subject matter content of the course itself. At any given point, the topic under consideration or the content being learned has a dual reference. It is an ongoing part or extension of the topics or content in that course which have immediately preceded it. At the same time it becomes the basis from which the further content is projected.

"Content" is probably the element considered as basic and indispensible when anyone thinks about formal education. A major purpose of education of any kind at any time is to transmit knowledge, and the usual criterion of how effective any education has been is the amount of knowledge the learner has amassed. In order to transmit the wisdom of the ages and the latest gadgetry of a highly mechanized society systematically, the content to be learned has been organized into curricula, programs, fields, divisions, departments, etc., and these in turn into individual courses. As a result, the catalogs of major multi-purpose institutions are a wonder to behold, and often a mystery to the uninitiated. Course titles range all the way from "Marriage and Family Living" to "Voltammetry and Amperometric Titrations", and back again.

The function of our planner is to look at the content of his course with bifocal vision, as it were. In the long view he sees the progression of the subject matter in its sequential order, its undergirding in previous work, its relationship to what comes beyond. In the shorter view, he sees each segment of the content in terms of specific facts and abilities to be mastered, specific items to provide meaningful learning and necessary insights.

The Physical Setting for Teaching and Learning

The third major part of the frame of reference within which teaching and learning take place is that of the physical setting. The classroom may be housed in a shining citadel of glass and aluminum or steel; it may be lighted at each seat, at laboratory station, demonstration table, and blackboard with just the right number of foot candles of illumination; it may be equipped with the latest models of projection equipment with all the necessary and desirable auxiliaries; it may be so located, or so effectively sound-proofed, that only the well tempered tones of the lecturer, or the earnest and scholarly voices of student discussants may be heard. A few of us who serve as college teachers have taught at one time or another in such a classroom. Recently I attended a meeting of a state-wide committee held in the plant of a major American industrial concern. In the education and training wing, where we met and through which we had a conducted tour, it seemed to those of us who were beleagured school teachers that all the classrooms were so constructed and so equipped. Perhaps we may have been pardoned for thinking how fortunate it was that educators could advise industry, which could afford it, what an ideal classroom should be like, so that possibly the wheel of fortune might turn again some time so that education could learn its own lesson from industry.

If our planner is connected with a venerable educational institution, however, the physical plant will usually reflect that venerability in good measure. His lecture, recitation, or laboratory class may be conducted in a room which has been remodeled or adapted from something which was adapted for something else which was adapted from something which was not entirely suited to whatever function it may have served in the first place. It may be too wide for its length, or visa versa. The chairs for students may be on a flat floor when the rows should have been placed on risers, or they may be on risers when they should have been flat. The lighting fixtures may be inadequate to the task they attempt heroically to perform, winter and summer, or downright quixotic in their functioning. The window may provide an elegant view of the heating plant, or of a grimy interior court where crumpled dirty papers blow about in the aimless wind. Provision for the use of audio-visual equipment may be non-existent, or at best inadequate. The cinder block walls may transmit sounds readily, so that the lecture from the adjoining room comes through in cavernous, echoing, dismal tones, like those the imprisoned Count of Monte Cristo first heard from the tunnel in the wall of his dungeon cell.

Disheartening though this may be, our planner must take all of these various features into account in preparing his plan of operation. Even simple instructional aids may serve sometimes to clinch or reinforce a point. The most elemental of visual aids, the blackboard, is considered by some instructors as if it were a part of the room decoration, rather than a useful, an almost invaluable, adjunct of instruction. The way in which instructional aids may be used effectively is discussed by other contributors to this Institute. The point of the preceding presentation is to highlight the necessity of making plans for classroom work in terms of maximum use of all the potentialities and resources under the instructor's command.

Individual Differences Among Students

We come now to the fourth element in our frame of reference, that is the students themselves. A great deal has been done by educational psychologists and others to analyze the nature of the young people who enroll in our schools and colleges. They have been individually and collectively weighed, probed, analyzed, cross-questioned, and tested with a considerable variety of inventories, tests, and psychometric measures of one kind and another. All of this is relatively modern, since the first controlled educational experiment of which we have any record was one proposed at a St. Louis meeting of the National Education Association in 1896. At that time a writer, Mr. Rice, proposed that an experiment be set up to determine whether or not students in the elementary schools ought to continue drilling on spelling a half hour each day or if it would be suitable to provide fifteen minute drills only. He was practically laughed out of the convention because his critics said that any fool could readily understand that students would learn twice as much in a half hour drill period as in a fifteen minute drill period. From the many research studies thus humbly sparked, however, we have discovered that the activities of the human mind are not so simply and mathematically deduced. We have come a long ways in our understanding of learning and motivation since that day, and yet there is much about our present student population that we still do not know with any finality.

A part of the difficulty is attributable to the fact that students are separate and distinct individuals, with widely differing levels of academic ability, and what may appeal to one person does not necessarily appeal to another, and what may motivate one student to put forth his best effort does not necessarily motivate another. The instructor who does his job most satisfactorily in any subject is the one who recognizes these individual differences and attempts to take them into account in planning and conducting the learning experiences in the class room. A recent analysis by W. Max Wise, published by the American Council on Education in 1958 titled, "They Come for the Best of Reasons--College Students Today," presents this picture of the individual differences concisely, as follows:

"College students today range from young to old, able to mediocre, idealistic to practical, naive to sophisticated, rich to poor; they are of all races, of all faiths--and of no faith. They are both full-time students and part-time students; they are both self-supporting and still dependent on their families. All these go to college, each for his own purpose. As the numbers of students continue to increase, so does the range of their individual differences."

Recent research into the personality structure of individuals is leading us to believe that there are fundamental differences in personality pattern and aptitude for learning which tend to modify still further our concepts of desirable learning situations and practices. The team of Stern, Stein, and Bloom has conducted some experiments in personality analysis and has come out with the proposition that personality structures tend to range from the very rigid to the very flexible type and that this variability tends to condition not only the kind of learning material which is particularly appealing to one or the other of these extremes, but also, the kind of situation in which one or the other types learns more effectively. These researchers indicate the personality patterns as the Stereopath or S Syndrome at one extreme and the Non-Stereopath or the N Syndrome at the other. The stereopathic personality is highly structured, organized, and compulsive, likes orderliness and system in all aspects of life, is the sort who insists upon "knowing the facts" in any discussion, and who has an optimum learning situation in a lecture presentation where the teacher gives out information in an authoritative way. The stereopathic personality is distressed if the authority in a field is questioned or criticized, and thrives best in a highly structured learning situation rather than in a free flowing one. The authors of this study have the following additional point to make regarding this kind of individual:

"Inasmuch as representatives of the S Syndrome might be expected to encounter considerable difficulty in tasks involving ambiguity, abstraction, spontaneity, and departure from conventional standards, it could be predicted that such persons would encounter particular difficulties in such areas of a general education program as the Humanities and the Social Sciences. It is in these areas of the college program in question where considerable emphasis is placed upon abstract analysis, relativity of values and judgment rather than fixed standards, and an intraceptive rather than an impersonal orientation."[1]

The N Syndrome, of course, is the opposite in all these characteristics in that he prefers easy-going, fluid, free-wheeling situations, such as open-ended discussion sessions in small classes, he dislikes exact regulations, his pattern of personal activities is much more fluidly structured, and he has no hesitation in questioning experts or even in contradicting an authority.

If one should follow analyses of this kind to a logical extreme, he might visualize the day when one kind of learning program and material might be set up for the stereopathic types in our institutions of higher learning and a completely different type of material and approach be provided for the non-stereopath. The authors of the studies cited are careful to point out, however, that rarely does one encounter a complete stereopath or a complete non-stereopath, since most people tend to fall somewhere between these extremes and to combine elements of each in their make-up. There are, however, certain tendencies toward one or the other syndrome, and this leads to interesting speculation, which seems somewhat less than fanciful in view of such electronic educational devices as test scoring and teaching machines.

At the University of Minnesota a paper and pencil instrument for the determination of basic personality patterns has been developed which carries the title of the Minnesota Multiphasic Personality Inventory--usually alluded to merely by its initials of MMPI. In speculating recently upon future developments in the field of personality measurement through the use of electronic computors, I was moved to prepare some doggerel which I have titled, "The MMFTE", or "The Minnesota Multi-Fusion Typo-Encounselator."

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[1] George G. Stern, Morris I. Stein, Benjamin S. Bloom, Methods in Personality Assessment, the Free Press, Glencoe, Illinois. 1956. p. 191.

The MMFTE

(or, the Minnesota Multi-Fusion Typo-Encounselator)

A view of current trends may show
Marked changes from the status quo-
And this may be our college scene-
The Man replaced by the Machine.

Counseling booths are awesome sights
With blinking green and crimson lights,
And for the ego-id defective,
Computers programmed non-directive.

Each neural impulse will be caught
By polarized electric thought-
Each profile matched to proper goal,
Each patterened on the structured whole.

So Syndromes S--the stereopath
Will all be majors then in math-
But Syndrome N will take the part
Of creativity in art.

The function of the Counselor then
No longer is by word or pen-
Instead, by program electronic,
He'll tape analyses Platonic.

PLANNING WITH A PURPOSE

After the above rather lengthy consideration of the four elements which condition the teaching and learning process, namely, (1) the total program of which a particular course is a part, (2) the subject matter content of the course itself (3) the physical setting in which the teaching and learning takes place (4) the nature of the learners, we come to a consideration of the purposes or objectives toward which the classroom learning is beamed. This leads us to the question which is surely at the heart of any consideration of planning for instruction, and that question is, what are the students supposed to learn in this particular course or in this given class session?

The prefaces to bulletins and catalogs of colleges and universities throughout the United States are filled with noble declarations of intent as to what residence in that particular college or institution will do to develop young people enrolling there. Often these well-phrased and impressive statements are formulated by a faculty committee or a member of the administration, and, once embalmed in the preface to the catalog, are conveniently forgotten even by any faculty members who may have had a hand in devising them. It is unfortunate indeed that this is so often the case, since effective instruction must involve conscious planning around a pre-determined list of desirable outcomes of instruction and learning. The relationship between a catalog statement of objectives, however, and what goes on in the classroom may be remote indeed.

I am fond of a story which I have heard related about the Canadian political scientist and humorist, Stephen Leacock, who claimed that he had invented a new method of learning which he called "Learning by Association." "All that is needed," said Leacock, "is to start with one known fact, and then, by making the proper associations, one is led to learn the new facts. "For example," said he, "Let us consider that we wish to learn the names of the Presidents of the United States in the order of their administrations. We start with the given name of Washington as the first President, and by making the proper associations, we are able to construct the entire list. We make the associations as follows: When we think of Washington, we think of washing. When we think of washing, we think of the Chinese. When we think of the Chinese, we think of missionaries. When we think of missionaries, we think of the Bible. When we think of the Bible, we think of Adam, the first man in the Bible--and there you have the chain of association--Washington, the first President, and Adams, the second President."

All too often the kind of learning engendered by classroom activities has what I would call a "Leacock association" to the objectives in the printed catalog. An institution may have as its stated policy the finest list of objectives in the world, but these will be invalidated completely unless the individual teacher in the classroom plans to implement them by working them into the day by day conduct of the classes under his jurisdiction. All too seldom do college teachers give any considered thought to the different kinds of objectives they wish to achieve and the different kinds of classroom experiences they will provide to realize these objectives on the part of as large a number of students in the class as possible.

VARYING TYPES OF LEARNING

Many experiments have been conducted and many analyses made by students of educational psychology to attempt to divide the objectives of learning at various levels of schooling into different categories indicating different types of learning outcomes. A general listing of these types is (1) knowledge of facts (2) understanding of basic concepts (3) ability to analyze and synthesize (4) attitudes or points of view or values (5) interests or motivating factors. Many studies which have been made indicate that in general there is a positive relationship among these various factors, but that the positive correlation is not necessarily high. That is to say, while the student who knows the facts of a lesson or a course quite thoroughly may be expected to have learned other desirable things also, such as basic understandings, and ability to generalize from the data he has studied, and positive attitudes toward the content, there are instances indicating that these other outcomes do not necessarily follow from a knowledge of facts. There are many teachers, however, who are firmly convinced that knowledge of the facts of course content is such a basic ingredient that it is the one on which sole emphasis should be placed, and that, accordingly, it is not necessary for the instructor to concern himself about other kinds of learning. This is a comfortable assertion because it relieves the instructor of thinking too seriously about other kinds of desirable learning. It also enables him to construct examinations which place emphasis upon factual learning only, and to grade on this basis. This is both an easier kind of examination to prepare, whether it be subjective or objective, and also gives the instructor a basis for so called "impartial judgment" which he considers unassailable. But the alert and thoughtful instructor cannot rest so comfortably upon this presumption.

In the field of liberal arts education, which is the only one about which I can speak with any confidence, there has been a definite trend toward emphasis on differing kinds of outcomes of learning over the past few decades. This is not to say that good teachers everywhere and always have not been conscious of other kinds of outcomes besides factual learning, but, until recently, we have had few means of measuring other kinds of learning, and therefore the attention of teachers on a broader scale has not been so systematically directed toward such outcomes.

There must have been, I am sure, trends somewhat similar in the field of engineering education. I can remember rather graphically a few of such changes in my own collegiate experience. When I was a freshman at the University of Minnesota some hundred years ago, for example, I can well remember stopping behind the mechanical engineering building occasionally to watch the engineering students pour molten metal into sand molds as part of their training in forge and shop classes. In those early days a good deal of collegiate learning was on the "how to do it" levels rather than being concerned with what we might call the higher mental processes. Many years ago the forge and shop courses disappeared from our mechanical engineering program, I understand, and have been replaced with courses which stress, more and more, ideas and conceptual content. This trend toward upgrading the college program has been going on, perhaps imperceptively, for a long time. A good example is cited in a recent history of higher education, in which the authors comment:

> "The whole tendency of the college was to move on to the work of a higher grade by dropping some subjects down into the secondary school. Thus, in 1720, when Jonathan Edwards was in his senior year at Yale, his class studied Euclidian geometry. In 1743, President Clap refers to geometry as a study of the sophomore year. In 1825, the same subject was dropped to the third term of the freshman year. Thirty years later geometry had become a requirement for admission to Yale."[2]

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[2] John S. Brubacher and Willis Rudy, Higher Education in Transition. New York: 1958. Harper & Brothers. p. 13.

In the so-called "good old days", there was also a prevailing idea about the study of subjects which might be called the "mental discipline concept." This was analogous to the taking of medicine in which the assumption was that the worse the medicine tasted, the more beneficial it must be. In the school sense, the idea was that the harder materials were to learn, the better they were for the development of the mind. The mind was regarded in the same light as a muscle of the body, which by exercising itself upon difficult feats of memorization, would be strengthened to the point where it could cope with other materials and situations effectively. This earlier stress on mental discipline has now been replaced with problem solving activities and meaningful experiences which students will find more directly useful in meeting the problems of living and making a living.

In liberal arts education the emphasis is increasingly on what we may call the "pervasive" outcomes of learning, meaning those which underlie various forms of content and often serve as integrating elements. Beyond the mastery of facts, which must be basic in any learning situation, five of these so called pervasive outcomes might be listed as follows:
(1) application of knowledge, or problem solving (2) critical thinking
(3) integration of learning into meaningful wholes (4) values
(5) creativity.

OPPOSING PHILOSOPHIES OF EDUCATION

Some years ago a heated controversy developed between proponents of what might be called a fundamentalist point of view in educational philosophy and a so-called progressive point of view. Although it is easy to over-simplify the differences between these two groups, it might be noted that the essential basis of conflict was that the fundamentalists believed in basic learning and drill on the factual content of traditional subject matter fields such as English, history, mathematics, spelling, and grammar, coupled with a rather stern form of external discipline. The progressives believed that all aspects of the learner should be considered, his emotional as well as intellectual complex, and that young people should be encouraged to experiment in new directions, should not be unduly inhibited by repressive discipline, and should engage in school activities which enlisted their interest as an aid to learning. One group based learning on the segments of established disciplines, organized in terms of the concepts of scholarship, and focused primarily upon mastery of content. The other considered learning as an adjunct to personality development and approached subject matter content through activities which were meaningful and interesting to students of any given age group.

A DOUBLE PERSPECTIVE ON LEARNING

The bitter feud between proponents of these two views lasted over a long period of time, and fundamentalism was revived by the launching of the first Russian Sputnik in the fall of 1957. School practices have been modified by the influence of both of these philosophies, and earnest students of the teaching and learning process have more recently attempted to reconcile these positions to some extent in establishing objectives of learning. These persons indicate that the learning of content in a given course or class session is the inescapable minimum level of accomplishment for acceptable progress. They are not content to stop with learning of factual content, however, but endeavor to assist students to attain also certain other abilities or types of learning, such as the development of efficient work habits and study skills, the development of effective ways of thinking, the development of socially acceptable attitudes, the development of interests, and the development of appreciations.

This list may seem of remote concern indeed to the young instructor of engineering subjects, who may not consider himself to be the least involved with progressive practices or philosophy. If planning is to be done intelligently, however, for effective instruction in engineering subjects or any others, instructors must be concerned with outcomes other than those of learning factual content. One way in which it is possible to reconcile other desirable learnings with learning of factual content is to construct a two dimensional chart which would state the objectives for a given section of content in a field of teaching. Along the vertical margin of the chart, for example, the topic and subpoints of factual elements and basic concepts to be learned could be listed. Above, across the horizontal part of the chart, could be listed certain basic abilities which may be considered as desirable adjuncts of factual learning. By constructing a chart of this kind, the instructor could determine which part of the content could be capitalized upon to develop other desirable learnings and could mark these in the manner indicated in the chart below. While it might be argued that the construction of such a chart for every unit or topic of instruction would be mere busy work, an exercise of this kind undertaken seriously by an instructor once in a while should serve to make him conscious in his planning and teaching of outcomes other than factual learning and should give him leads, perhaps, as to how he might conduct a class in order to develop these behavioral learnings most effectively. (See page LL18 for CHART NO. 1 - TWO DIMENSIONAL CHART)

The chart is illustrative only, and somewhat different planning might result in the X's being placed in different squares. It does show, however, how learnings other than "memorizing the facts" may be related to the latter, and that the resourceful instructor need not necessarily by-pass one type of learning outcome to concentrate on another. The teacher of engineering subjects who gives thoughtful consideration to the kinds of learning which are desirable in the courses he teaches might certainly come up with quite a different list of behavioral categories to be distributed across the top of any chart with which he might experiment. Such experimentation, in the interest of resourceful planning, however, should surely broaden the dimensions of his teaching and enrich the classroom experiences of his students.

CHART NO. 1

Topic: Formation of the National Government, 1787-1789

Content material to be learned	Other learnings to be achieved						
	Understanding of basic terminology	Ability to locate additional relevant materials	Critical evaluation of sources of information	Ability to identify central issues	Ability to draw warranted conclusions	Ability to see relationships to current problems	Etc.
A. Why were the Articles of Confederation not satisfactory?							
1. Reasons for and effect of limited powers of central government.	X		X	X	X		
2. Conflict between large and small states.	X	X		X		X	
3. Absence of a federal judiciary.	X				X		
4. Federation of states too loose.	X	X	X				
B. What were the major problems of the Constitutional Convention?							
1. Efforts of "Union men" to influence public opinion.	X			X		X	
2. Desire for state sovereignty.	X	X		X		X	
3. Opposition to congress.	X	X	X	X	X		
4. Desire for confidential deliberations.	X	X	X				
5. Arguments over make-up of new Congress.		X		X	X		
6. Need for compromise	X	X	X	X	X	X	
C. How did the new Constitution differ from the Articles of Confederation? 1. Etc.							

INTERRELATING CONTENT AND TEACHING METHOD

Although the term "teaching methods" is anathema to many academicians, it would seem folly indeed to ignore the contributions which investigators in this field might make to effective teaching of engineering subjects (or any others.) Accordingly, rather than relying on an intuitive approach, or the memory of courses in which he was enrolled as a student, our young teacher should consider how he might vary his daily classroom presentation not merely for the sake of providing variety (although this in itself often provides desirable motivation and increased interest) but to utilize methods of teaching which may provide more effective learning than the usual lecture, laboratory, or recitation. As a further experiment in broadening his repertoire, the serious-minded teacher might try constructing another chart to point-up relationships between segments of content and various procedures which might be used in the teaching of that portion of the con tent. As a further illustration of this other dimension of planning, the following chart is presented which utilizes the same topics of content as the previous chart. In this case, however, the top margin lists teaching methods. Some ingeneous soul might possibly improve upon these two charts by combining them into a single three-sided "master copy," presumably with blue and red and green inks and X's and check marks of a suitably distinguishable variety. See page LL20 for CHART NO. 2.

CHART NO. 2

Topic: Formation of the National Government, 1787-89

Content material to be covered	Lecture	Panel Discussion	Recordings	Moving Pictures	Class Discussion	Film Strips	Guest Lecturer	Oral Reports	Written Reports	Field Trip	Demonstration	Class Committees	Book Reviews	Laboratory	Individual Projects	Short review quiz	Buzz Session	Drill review	Etc.
A. Why were the Articles of Confederation not satisfactory?																			
1. Reasons for and effect of limited powers of central government.	X				X				X								X		
2. Etc.													X		X				
3. Etc.		X			X			X											
B. What were the major problems of the Constitutional Convention?																			
1. Eforts of "union men" to influence public opinion.					X				X						X				
2. Etc.	X		X														X		
3. Etc.					X			X											
C. How did the new Constitution differ from the Articles of Confederation?																			
1. Etc.	X			X									X						
2. Etc.	X						X								X				

LL20

PLANNING SPECIFIC CLASSROOM ACTIVITIES

In the previous discussion considerations have been pointed out concerning the framework within which planning for college teaching and learning take place. The elements of this framework were four. (1) The total program of which a particular course is a part (2) The subject matter content of the course itself (3) The physical setting in which the teaching and the learning take place (4) The nature of the learners. Subsequently, an extended discussion was presented concerning the setting up of objectives of learning for students. It was indicated that instructors, to plan adequately and effectively, must give thoughtful consideration to the different kinds of learnings which they wish to encourage in addition to the learning of factual content, that is, such matters as critical thinking, ability to see relationships, ability to analyze material, ability to generalize from discrete data, etc., etc. It was proposed that instructors experiment with setting up a two dimensional chart for some of the topics or units which they would teach, indicating the sub-divisions of the content along the vertical side of the chart, and the kinds of learnings which they wish to dove-tail into the learning of factual content across the horizontal part of the chart. By making marks in the appropriate squares of this grid, the instructor will be able to work out, either on paper or in his own mind, plans for using the factual content to develop other desirable learnings and to reinforce these as he goes along. If these activities are entered into, both instructor and students may well find that they are getting much more satisfaction from classroom experiences.

As a concluding item, it may be pointed out that there are different kinds of presentations and different kinds of lessons and that each of these requires its own specific planning. For example, one surely would not or should not use the same kind of approach, even in a lecture presentation, in introducing a subject to a college class as he would in conducting a review which followed the study of a portion of content, or which was a review of the whole course prior to the final examination.

In introducing a subject, instructors sometime assume that the student is already well motivated towards the particular content which he is teaching and understands sufficiently what it is he is expected to learn and how he should go about his study and learning. This convenient assumption is not always tenable, however, and many experienced and knowledgeable college teachers take considerable pains in the first class meeting or two to give the students in the class a general overview of the content to be covered, its relationship to what the student has studied earlier, its relationship also to the work which the student will have subsequently, and to develop in some detail the way in which it is desirable for the student to study and the kinds of learning which will mark effective and adequate progress. If the instructor merely plunges immediately into a consideration of content, as all too many do, the students may correctly assume that this is all that is considered important, and make no effort to do more than memorize the facts put before them in lecture, recitation, textbook, and outside reading. If, however, the instructor makes it explicit at the beginning of the course that he expects students to develop an intelligently critical attitude toward materials which they read, that he expects them to be able to generalize from discreet data, that he expects them to find sources of information other than those explicitly listed in assignment sheets or bibliographies, the student will make a determined effort to engage in these additional activities beyond learning factual content. Such a presentation is somewhat in the nature of a briefing session for a mission to be undertaken.

Effective methods of review have been studied by educational psychologists and a number of proposals might be made to those who are interested in making review lessons more than a mere dragging over factual content in the same old way. It is stated by writers in the field that the most effective kind of review is actually what might be better called a "new view" of content already covered. That is to say, rather than covering ground in precisely the same way in which it has been covered previously in the class, it is desirable to present problems which will require utilization of factual learning in a different context or to require the student to discover relationships different from those which he may have made when originally studying the content.

Certain kinds of material are presented most efficiently and effectively in lecture form, other materials are better developed through classroom discussion. Occasionally, audio-visual aids may be highly effective in reinforcing certain learning concepts or in presenting material graphically which could not be as well presented verbally. Laboratory classes provide an opportunity for a student to get direct contact with the materials in the field in which he is working, but many laboratory classes and exercises have been condemned as the so-called "cook book" type, wherein the student automatically follows directions and does not do any experimenting on his own with the result that no original learning takes place. Whatever the kind of lesson or class to be conducted, whatever extra materials are available, it is essential that the instructor must plan carefully if he is to make maximum use of the time at his disposal.

As a final point, it may be stated that it is assumed that the instructor will use the most effective means of carrying out routine classroom activities. That is to say, that if papers are to be distributed, the instructor should arrange to have this done expeditiously by one or more students rather than taking class time to hand out papers individually himself. If a pre-determined seating arrangement is made, a seating chart should be available so that the roll can be taken with the loss of as little time as possible. If supplies are to be given out for laboratory work some method of distribution should be devised which would require as little standing in line on the part of students as possible. It would seem that particularly in the field of teaching of engineering subjects, instructors might consider the routinization of mechanical aspects of the conduct of the class as a challenge to their concept of efficiency. For classroom time is precious, despite the fact that students and faculty frequently waste a great deal of it. Instruction should be planned to occupy all of the time available to the instructor with a minimum of distraction and unnecessary delay. For effective learning should take place---and will take place--in a classroom situation which is well managed and where the entire class presentation is brisk and businesslike.

WORKSHOP ON LESSON PLANNING

Thomas Rockwell

Ohio State University

I. Purpose:

The purpose of this workshop is to demonstrate the principles of lesson planning as applied to a specific technical lesson. Each YET participant will prepare and present to his subgroup a detailed lesson plan on one of the technical topics listed below. (Note: In presenting his plan the participant is not asked to give the lesson but rather show the organization necessary in its planning.) It is presumed that by actually preparing a lesson plan the YET will achieve maximum benefit from the morning sessions on the principles and philosophy of lesson planning. Each subgroup will be composed of YETS with similar technical fields of specialization so that a comparison of approaches in lesson planning between the YETS can be made. It is anticipated that lively, profitable discussion will emanate from this comparison.

II. Group Division:

During the afternoon workshop the participants will be divided into subgroups (Divisions) roughly approximating the various technical fields of engineering represented. This is necessary for two reasons - first to allow the discussion of lesson planning to be conducted at a technical level in the language of the field and secondly to allow more individual participation. These groups will be assigned as follows:

I Forman, chairman; Bender, Brass, Hoenig. Michaels, Smith, and Moore

II Gaylord, chairman; Flammer, Fletcher, Knott, Nicholson, Pritchett, and Jacobs

III Gilbert, chairman; Fisher, Kapner, Landis, Rodriguez, Zuspan, and Lagerstrom

IV Grogan, chairman; Golde, McCausland, Merrill, Rubin, McDaniels, and Giordano

V Roberts, chairman; Woodruff, Moy, Poage, Reemsnyder, Eppes, and Harman

It is recognized that the teaching backgrounds in these groupings are not truly homogeneous but in most instances will permit a technical rapport (which incidentally few of us in teaching ever experience considering the heterogeneous backgrounds and skills of our students.)

III Topic Selection:

In order to arrive at technical topics for the subgroups, suggestions were solicited from the participants earlier this summer. It is not surprising that there was little agreement even among those of the same field of specialization. However, from the list submitted, four specific lesson topics for each subgroup are given below. It is intended that the subgroup members rank them in order of preference. The chairman will then democratically select one of these for the lesson plan to be developed. The MET chairman will also be asked to clarify and further delineate the topic for the subgroup if it is deemed necessary. This will insure as far as is possible the preparation of the same lesson plan by all the subgroup participants.

I. a. Introduction to the first law of thermodynamics

   b. Single degree of freedom vibration (development of the differential equations of motion)

   c. Column buckling

   d. Modulus of elasticity

II. a. Fluid statics - pressure measurements

   b. Unit load theory

- c. The impulse - momentum principle in fluid dynamics
- d. Use of plane table in surveying

III.
- a. How to write a Unit Operations Laboratory Report
- b. The concept of energy balance
- c. The Reynolds number
- d. Introduction to radiation heat transfer

IV.
- a. Use of vectors in ac circuit analysis
- b. Determination of speed-torque characteristics of induction motors
- c. Thevenin and Norton Theorems in circuit analysis
- d. The idea of an equivalent circuit

V.
- a. Newton's Law F = M A
- b. A review lesson in differential calculus (either prior to an exam or prior to a course in which differential calculus is required)
- c. Dimensional Analysis
- d. Straight Line Depreciation

IV Procedure:

1. 1:00 - 2:00 The preparation of the lesson plan by each participant.

It is suggested that each YET do some preparation prior to the workshop so that he won't be caught "cold" on the subject. The lesson plan should be legible as possible so that it can be flashed on a screen for presentation to the group. This lesson plan should include content, progression of subject matter, approximate amount of time to each part, teaching aids required, key questions to measure student understanding, etc., etc. It is not suggested (nor is it expected) that each YET follow a given format in the lesson plan. It will be the variety in approach that shoule be of greatest value to the workshop.

2. 2:00 - 3:00 The presentation and explanation of the lesson plan by each YET to the subgroup.

With the use of visual aids (opaque projectors) it is hoped that approximately ten minutes per YET will be sufficient time to present the lesson plan. The MET chairman is asked to regulate this time so that each may be heard. If step 1 is completed before 2:00 PM then the subgroup may begin step 2 immediately. This presentation and explanation of a specific lesson plan may involve questions of clarification from the subgroup. However, it is suggested that questions of disputation or disagreement be held until the next stage.

3. 3:00 - 3:30 A review and discussion of the various approaches to the lesson plan.

Led by the chairman, the subgroup can now discuss the various approaches to the lesson plan, the different teaching techniques presented and the reasons behind various plan constructions. The MET chairman is asked to record the highlights of this unstructured discussion noting the similarities and dissimilarities in introduction, emphasis, progression, timing, teaching aids, etc.

4. 3:30 - 4:00 All subgroups will reassemble for a critique of the workshop highlights presented by a panel made up of the subgroup chairmen. Here we are interested in finding the major results in lesson planning which cut across the boundaries of the individual fields of specialization. The speakers from the morning session will be on hand to answer questions from the floor pertaining to the experience of the participants in their lesson plan construction and to comment on their observations of the workshop.

EVALUATION OF INSTRUCTION

Paul L. Dressel
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The phrase, evaluation of instruction, contains two words of broad and uncertain meaning. Evaluation suggests the placing of a value upon an object or process which presumably must be of concern, else indifference rather than appraisal would be the behavior manifested. Evaluation may connote an ultimate appraisal but only if both the entity appraised is itself static and the standards applied are valid. The judgments of human beings -- both individually and collectively -- change, so that evaluation, even of a static, unchanging object or function, might be different at one time than another. It is this doubt about the reliabilty of an evaluation of instruction, or, conversely put, the distrust of its subjectivity which causes some individuals to display disinterest or antagonism toward it.

The other word of the title of this paper, which is something less than crystal clear in meaning, is instruction. It is not possible to evaluate without some insight into the nature and function of that which is evaluated. Certainly, there are different views as to the functions associated with instruction. One is that the person who knows can teach. In this conception of instruction, the instructor, with encouraging cries to announce his altruistic presence, tosses abroad his kernels of wisdom; the students, like chickens, hurriedly gather to gulp them down. Highly motivated individuals may learn through such procedures, but the view of this paper is that an individual who functions in this manner is not engaged in instruction. There is more to raising chickens than corn and eggs. In the following section, the nature of instruction as here regarded will be clarified by delineation of several functions of instruction.

1. The Functions of Instruction

The first function of instruction is that of motivation of the student. It is not unreasonable to assume that a student coming to a university has some basic motivation toward self-improvement. It is perhaps too much to assume that this basic motivation carries over to provide adequate motivation in each and every course which that student may be required to take by virtue of selection of a certain curriculum. A young man, interested in engineering, may lack any conception of how mathematics or the physical sciences provide the basic principles and theory for engineering practice. Thus, the student needs to be brought to the point of seeing the relevance of the particular course in terms of his ultimate goals. It should be made clear to him what changes it is that the course attempts to promote, the importance of these changes, and the necessity of them for a later role in which the student has already engaged to project himself. Until the student recognizes the importance of a course and is concerned about his inadequacies, it is not to be expected that he will take on very much personal obligation or display any great concern about change.

The second function of instruction is that of demonstrating to the student just what it is in the way of new knowledge, behavior, or reactions that are expected of him. This obligation also involves some supervision or guidance of the student's efforts in trying to acquire these reactions. Laboratory instruction commonly provides one of the best illustrations of this particular function. The students, as a group, may be given a demonstration of how to utilize certain equipment. Some of the individuals of the group may proceed at once to operate effectively on the basis of this demonstration. In other cases, individuals will have to be observed, comments and suggestions made, and perhaps actual physical assistance supplied in manipulating the individual through the operation once or twice. Another example is found in the mathematics classroom, wherein a general demonstration of how to deal with a certain type of problem is frequently followed by a request that everyone go to the board and attempt the solution of a similar one. Those individuals who have difficulty may then be given assistance by the instructor to insure that they have at least once carried through the procedure just presented.

A third function of instruction is to provide extensive and meaningful materials upon which the student can work and practice. It is not sufficient to assume that either a demonstration or the actual supervision of a student in one experience with a new bit of behavior will yield mastery. It is hardly much better to suggest to the student that he needs more practice and leave it to him to select the materials and proceed on his own. The teacher must realize that what he does and what is done in the classroom is only preliminary to the significant learning which comes about only when the student repeatedly engages in the behavior until it has become part of his repertoire of understanding, skills, and abilities.

The fourth function of instruction is that of providing the students with some satisfaction by indication that he is making some progress. This involves pointing out to the student what is good about what has been accomplished, although it is sometimes necessary also to point out the weak and inadequate aspects of the performance. Unfortunately, grading practices usually emphasize the poor aspects of a performance rather than the good, simply because the "A" is thought of as the only really satisfactory performance, and any reduction of a grade below and "A" is regarded as coming about because of inadequate or bad performance. Too frequent grading may therefore injure or interfere with the learning process.

The fifth function of instruction is that of organizing the work so that the sequential cumulative aspect of it is readily apparent to the student. The learning of isolated facts or skills must be interspersed with activities which give some indication of how these skills come together. No tennis instructor would long hold the interest of any large number of students if over weeks and months the students were restricted to the practicing of each type of stroke without ever having any opportunity of playing, however inadequately, a game of tennis in which these are put together in a meaningful way. Completely repetitive practice of particular skills is merely boring to the student and the loss of incentive will interfere with mastery. When the skill or understanding is seen in relationship to other demands and other skills and understandings, such boredom may be mitigated. The work of a class should be organized so that there is some novelty and increasing complication. The combination of these two will aid in maintaining interest and causing greater concentration.

The sixth function of instruction is that of providing the student with high standards of performance and with means for judging the extent to which his performance meets these standards. If this is to function as an incentive for continuing learning and increased mastery, it must proceed on some basis other than the common testing practices. These emphasize completion of some phase of learning and assign a grade from "A" to "F." Such practices encourage the student to settle for a satisfactory grade rather than a high-quality performance. Thus the student who receives a "C" is, in effect, told that he has satisfactorily completed that particular unit of work. The emphasis is not on what might be done to attain a greater level of mastery, but rather on moving to the next task.

If these six functions are accepted as descriptive of the obligations of college and university instruction, then it becomes clear that an attempt to evaluate instruction could proceed by examining the extent to which these functions are fulfilled. It could, likewise, proceed by asking the extent to which these functions have resulted in significant learning or change in the student. One approach involves an examination or evaluation of the process; the other involves attention to the results. The following sections of this paper will consider both.

2. The Role of Evaluation in Learning

Although evaluation is frequently regarded as a judgment-making process to be applied after learning has taken place, the fact is that evalutaion has a significant role in the learning process. In fact, each of the functions of instruction which have been discussed in the preceding section may be demonstrated to require or utilize certain evaluation practices for their fullest implementation.

Careful testing or evaluation of the knowledge, skills, and abilities of individuals at the beginning of a course may be used to demonstrate to the students that they have deficiencies with regard to the kinds of behavior which the course is designed to promote. This indication of deficiency, properly used, can provide motivation by showing the student the need and significance of the course.

The development of any evaluation instrument involves operational definitions of the objectives of a course in that we are asking a student to engage in an activity which will demonstrate to us whether or not he has achieved these objectives. Thus, evaluation forces the instructor into an operational definition of purposes and a concrete indication of the kinds of behavior desired of the student. In this manner the evalution instruments and the particular task involved in it provide a demonstration of the new behaviors which the student is supposed to acquire.

Since the tasks involved in an evaluation instrument must be a sampling of those with which the student is expected to cope successfully, materials developed for the purpose of evaluation also may be regarded as practice exercises. Repeatedly it has been the experience of evaluators in working with teachers that materials developed for a test or evaluation device are seized upon by the teachers as some of the best learning materials which they have yet seen. Furthermore, the taking of the test itself may be considered an opportunity for practice. Here, as already noted, the assignment of a grade to the test may invoke a feeling of finality with respect to the kinds of behavior involved up to that point. An alternative practice is to use test exercises or even what appear to be full-dress tests simply to provide the student with a concrete indication of his mastery of materials up to that point. The unsuccessful student can ascertain his deficiencies and he may then be expected to prepare more adequately for a later test scheduled to fulfill the necessary grading function.

Clearly, tests and evaluation instruments can and should provide evidence of the student's progress. In reviewing the student's performance, those aspects upon which he has done particularly well and particularly those in which he has displayed some originality should be remarked upon. In other cases, either by annotation on the test or by discussion, the student should be provided an opportunity to grasp the principles and concepts which he has either misunderstood or misapplied.

A test or evaluation device which requires of the student only routine tasks upon which he has been repeatedly drilled may demonstrate mastery of skills but it does not involve the student's ability to apply principles. Therefore, a portion of every test should include tasks which are new to the student but which can be adequately handled by application of the knowledge, skills, and abilities which he presumably has mastered up to that point. Thus, the test itself contributes to the student's seeing that the individual pieces of a course do combine and add up to something beyond what has been fully treated in the classroom. The task of organizing course materials in a sequential cumulative way is not solely a matter of logical analysis of the content. The difficulty of any content is not solely an intrinsic quality of the content; it is also, in part, determined by the reactions of human beings to it. Sequential organization of content then poses itself some research problems on which evaluation is necessary. Alternative organizations may reveal that one organization is preferable to another because of increased motivation and understanding by the students.

An evaluation instrument involves the decision by an instructor as to just what aspects of a course the student can reasonably be expected to handle adequately. In turn, then, the evaluation device presents to the student an explicit definition of the behavior in which he is expected to demonstrate proficiency. The number of items right or the grade given should suggest to the student something of the extent to which he has achieved the kind of standards which the instructor and others think appropriate for this course. When subjective judgment is involved, as in report writing, the student may be encouraged by recourse to the judgment of his peers as well as that of the instructor. Thus, if the student's report is submitted to other students who find it incomplete or impossible to understand, the writer may be forced to look at his production in a new light. The realization that, whether or not he knew the material, he was unable to adequately communicate it to his peers is often more devastating than the criticism of the professor.

From this analysis, it should be clear that evaluation can and should play a significant role in connection with each of the six functions of instruction. If the definition of instruction implied by functions mentioned in the first section is accepted, evaluation of the instructional process may proceed by determining whether the instructor accepts obligation for these functions and by the extent to which he engages in overt practices which make this apparent. In particular, since evaluation is, in some cases, a necessary and in other cases a major path to the accomplishment of the six functions of instruction, instruction may be evaluated in part by the extent to which adequate evaluation practices are evident in the instructional program of the individual instructor.

3. Approaches to Evaluation of Instruction

We have already noted that there are two rather different paths to the evaluation of instruction. One is to look at the process of instruction itself and the other is to look at the results of instruction. We shall first consider several approaches to evaluation of the process, then consider some of the possible approaches and problems in the evaluation of the results and, finally, look at several other possible approaches to evaluation which are not clearly one or the other of these two.

Student Perception of Instruction

Perhaps the most discussed approach to the evaluation of instruction is that of student perception of instruction. Usually, this proceeds by the collection of student reactions either by means of an objective rating scale or by brief structured essay responses wherein the student's attention is focused on each of several issues in turn.* Unstructured written responses by students are frequently very useful to the individual instructor in appraising his own success, but such student reports scarcely yield any objective comparative evaluation of a number of instructors. Because of the work involved in processing such unstructured essay responses, the use of some form of rating scale is very common. The student is variously asked to evaluate by checking a number of descriptive adjectives such items as the kind of assignments made or to rate characteristics by indicating whether this particular instructor is low, average, or superior with respect to other instructors which the student has had. Extensive research has been done on student ratings of instruction, and, generally, though not in all cases, it has been demonstrated that these ratings are fairly consistent regardless of grade or class level of the student. Student ratings have sometimes been shown to correspond closely to those of the instructor's associates although the latter may be more oriented to research output than to teaching. Despite the evidence of both the reliability and validity of student ratings, instructors are generally hesitant about accepting student ratings and even resentful when these are forced upon them. It may be more politic to ask the student to rate the course rather than the instructor. In rating the instructor, the student is asked to act as a judge of the adequacies of the instructor, perhaps inclusive of personal characteristics, scholarship, and his classroom performance. This approach may imply to the student that he is the ultimate authority as to the adequacy of teaching. Although Aristotle suggested that the dinner guest rather than the chef should be the ultimate judge of good cookery, the dinner guest who makes no allownace for his own appetitie or his prejudices in regard to food can hardly furnish a generally valid evaluation of the dinner.

A student may reasonably be expected to have some responsibilities for his own learning. It may, therefore, be more appropriate to ask him to engage in a broader type of evaluation in reference to the course or in reference to the total learning experience rather than solely to the instruction. An approach to student appraisal which asks the student to indicate what he feels are the objectives of the course, that relationship he found between the activities in which he engaged and these objectives, what he did in the way of studying for the course, and what changes in views, attitudes, or behavior generally have taken place as a result of the course causes him to reflect on his own behavior as well as on that of the instructor. Into the student responses to such questions the instructor can readily read something of his own adequacy but with somewhat less defensive reactions than when he feels criticisms are directed entirely at personal shortcomings. The reception of such ratings is also probably eased by the fact that this type of student appraisal does not lend itself to easy inter-instructor comparison.

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* Examples of two such forms currently in use at Michigan State University are attached.

Peer and Self-Appraisal

There are approaches to the direct appraisal of instructor behavior other than student rating. Observation by peers or by administrative superiors is regularly practiced in some institutions and probably should be more commonly the pattern in our colleges and universities. Some professors seem to believe in a concept of academic freedom which renders their classroom inviolate of intrusion by others except upon specific invitation. This makes of academic freedom a license which permits the professor to teach as badly as he wishes. Nevertheless, the prevailing tradition makes it difficult to start, in any institution, a policy of inter-class visitation involving all teachers except by unanimous consent of the unit involved. It is quite possible to establish the practice that all new appointees to a department will, during the first year or two, engage in such activity. Typically, this might proceed by relating the new instructor to an able professor who is teaching the same course. The new instructor can first visit his colleague's classroom. From this start an interchange of visits and extensive discussion of the observations soon naturally follow. This would provide the new person with an opportunity to view his instructional practices through the eyes of a more experienced individual and, at the same time, to learn some of the particular and unique features of this particular college, department, or course.

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For more careful analysis of the conduct of a classroom, recordings are very useful. The recording of one or more full classroom sessions, even if played back by the instructor only for his own amusement, will shortly replace some of that amusement by consternation and the determination to perform a little differently than before. If desired, other individuals may be brought into such a session for more extended analysis. Such recordings may also be used, as was done by Benjamin Bloom and associates at the University of Chicago, to analyze the thought processes of students in relationship to the manner in which the class was conducted.

A third approach to the appraisal of instructor behavior by peers is that of drawing upon subjective opinion and on research to make up a list of the characteristics of successful teachers. The usual difficulty with such lists is that the total impact of the list of all desirable traits is to suggest an individual whose full possession of such traits would make him something more than human. Furthermore, in some cases the characteristices found cannot be rationally applied. For example, one study purported to show that teachers who were raised in rural communities tended to be rated as more successful than those who were raised in large urban communities. The application of such a finding as this to either teacher selection or teacher evaluation can only be characterized as ridiculous. Furthermore, it is probably not the separate traits which make for a successful teacher but rather unusual combinations of traits found in particular individuals. There is some doubt that the trait or characteristic approach holds much promise as far as improvement of instruction is concerned, although it is no doubt true that the particular idiosyncrasies, characteristics, or qualities interfere with good instruction. The recurrence of a particular gesture or the recurrent use of a particular word or phrase may become so much a distraction that students become preoccupied with counting the number of times this behavior is observed. Yet, in other cases, such peculiarities may be one of the factors which endears the professor to his students.

On the whole, it makes more sense to consider what a teacher does rather than what he is. This is not to say that what he does is not in part determined by what he is. It is easier, however, to talk objectively about what the teacher does; it is also easier for the teacher to change what he does than it is for him to change his personality or background. Study of instructional characteristics is more likely to lead to improvement.

Evaluation of Purposes, Plans, and Materials

Evaluation of instruction may proceed by examination of purposes and plans and materials used in a course. In cases where a number of instructors are involved, the statement of purposes, the course plans, and the materials used will usually not indicate the point of view of each separate instructor but rather will be a compromise decision of the group which, nonetheless, affects the instruction of every person involved. Persons with extensive teaching experience can review these aspects of the course and make some judgment as to their efficiency in promoting the desired learning. These materials, plans, and purposes may be examined directly in relationship to student learning, especially if the existence of alternative practices or materials provide comparable data on the performance of students who have had these different patterns of experience. Where a single instructor is involved in a course, the purposes, plans, and materials are a direct indication of his own thinking about instructional matters, and either student appraisal or observation by peers will certainly, in part, be based upon these factors.

Evaluation of Student Learning

The effectiveness of the instructional process utlimately must, of course, be gauged in terms of student learning. Sometimes this point of view is carried so far as to deny any validity to student ratings, classroom observations, or any other process criteria. This is unfortunate, for objectives are sometimes stated for a course without giving thought to their implications for the development of instructional practices. In such cases, an attempt to evaluate outcomes may be unproductive simply because the process is unrelated to the stated purposes. Clearly, consideration of the process is desirable, for if careful examination of classroom practices, plans, and materials does not demonstrate some apparent relationship between practice and purpose there can be little point in attempting to evaluate results.

Those who hold to intangible unmeasurable objectives as being the most important outcomes of education would deny that evaluation of significant results is ever possible. Some professors have even carried this view so far as to assert that the mere fact that one finds a way of evaluating an objective is evidence that that objective is not important.

If one accepts the principle that results are the pay-off function in evaluation of instruction, it is necessary to specify how these results may be appraised. The ubiquitous course examination provides some evidence, but frequently some of the major objectives of a course are inadequately represented therein. In particular, one of the issues that arises is that of immediate and long-term objectives. The knowledge of specific materials covered in the course is the most apparent result of the course, and the one most easily evaluated. On the other hand, some of the more significant outcomes involving critical thinking, judgment, and the synthesis of ideas in dealing with complicated problems may not easily be evaluated for a single course, especially with the limited time usually assigned to such evaluation. For such pervasive objectives, there is some reason to doubt that a single course provides sufficient educational experience to make much difference in student behavior.

In highly technical and scientific courses, it may be assumed that most individuals come to the course with very little factual knowledge in the particular segment of the discipline covered, yet any assumption that the individuals are lacking in some of the skills and abilities which are goals of the course is probably unjustified. The skills and abilitities may not extend to the use of the facts of that course simply because these facts are not as yet known, but it might be found that the course contributes additional knowledge without having, in any way, increased the student's facility in use of the knowledge. There are real difficulties involved in separating these objectives but, to the extent that it is possible, a more adequate approach to evaluation of effectiveness is represented by a pre-post-test comparison in which both knowledge and the abilities involved in using that knowledge are sampled.

Most instructors will admit to some concern about changes in attitudes and values as possible outcomes of a course, although they may be unwilling to specify the exact nature of these. The appraisal of these affective outcomes is more difficult and less objective than the appraisal of cognitive outcomes. Furthermore, to indicate that certain attitudes or values are desired outcomes of a course is to suggest an indoctrination process and to encourage dishonesty on the part of the students who thereby learn that success lies in simulation of the desired attitudes or values, whether or not these are accepted as guides to behavior. Because of this possibility, attitudes and values should play a very minor role in the actual grading and credit process, even though changes in attitudes and values are almost certain to result from any course experience or even from contact with an instructor. It behooves the institution and the individual teacher to make some appraisal of the impact of learning in this regard. Certain attitudes and values which relate to the learning process itself may even conceivably be accepted as criteria for judging the progress of the student. Thus, the acceptance of the scientific method as a way for seeking scientific facts and validating scientific hypotheses really represents a value choice. It is doubtful that any engineering college would wish to award degrees to individuals who refused to accept or employ a scientific approach to engineering problems. In so doing, there are dangers which must not be overlooked. Tentativeness of opinion and objectivity constitute values which are much prized in the sciences and social sciences but adherence to these values must not be carried so far that students refuse to make personal commitments or become so completely relativistic that they have no ethical or moral standards.

Major changes in attitudes and values are probably not to be expected over a brief period of time, although this does occasionally happen. The individual coming to college is already reasonably mature and his attitudes and values have been formed over a span of 18 or 20 years. If one is to argue that these could, within a few months' time, be radically changed by a single course, the implication would be that this individual is lacking in depth and that successive courses may be equally effective in bringing about radical changes in other directions. Evaluation of affective outcomes, if it is to be done in any meaningful way, requires faculty agreement and the formulation of procedures which transcend particular courses and perhaps even extend over the entire span of years involved in the program.

Other Criteria of Instructional Effectiveness

Some individuals would accept an evaluation of a course or instruction as being found in the number of students who become sufficiently interested to continue further work in the area. Thus, introductory courses in some of the liberal arts areas are occasionally evaluated by the number of majors which are attracted to the department. In sequence courses, such that success depends upon the work of earlier courses, the evaluation of instruction in a particular course may, to some extent, be made by looking at the quality of the work of students in later courses. The mores of academe dictate that any instructor in an advanced course hold the opinion that the previous work of the students leaves something to be desired, but there is frequently a recognition or suspicion that the preparation of the students of certain instructors is better than that of students of other instructors. With care it may be possible to sort out the factors involved in such a way as to provide some evidence of the quality of instruction. Where success in a course depends upon a sequence of preceding courses, it is unlikely that such evaluation can ever be related back to a single course or single instructor, but this approach can still be a valuable appraisal of the general quality of the learning experiences provided.

Still other criteria have been proposed as a basis for evaluating instruction. Some persons have suggested that the correlation of ability and grades might be used. The implication seems to be that, if an instructor is effective, students will achieve in accordance with their ability, and hence the correlation will be high. It may equally be argued, and there is evidence to demonstrate this, that the instructor who pays attention to the weaknesses of his students and attempts to do something about them will end up with lower correlations and yet, conceivably, may have done a better job of instruction than someone who ignored individual differences.

Research and scholarly productivity may be regarded as an aspect of instruction broadly conceived. However, it seems more appropriate to regard the college professor as being engaged in a number of different activities. In this view, research should be regarded as a separate activity. A reasonable view seems to be that a good researcher may or may not be a good teacher. However, scholarly productivity, regarded in the sense of alertness to developments in the field and continuing attempts to relate these new materials to those already included in various courses is a significant aspect of good instruction. Certainly, the instructor who does no current reading or thinking soon becomes out of date; although his instructional techniques may be good, his overall impact on the student cannot be regarded as entirely satisfactory.

Distrust of Evaluation

One of the problems in evaluation of instruction is that procedures which are applied externally and related to financial reward and promotion assume something of a threat for the individual. The very fact that he is threatened by the evaluation means that he is less capable of taking advantage of the findings and making any improvement. Thus, the external evaluation, insofar as the instructor is concerned, assumes very much the same role as the grade does with regard to the student. In the next section, attention will be given to consideration of some of the purposes of evaluation of instruction, with the possibility in mind that clarification of these purposes and proper relation to any particular evaluation practices to these purposes may help to mitigate the threat.

4. Purposes of Evaluation of Instruction

The first, and perhaps the most commonly recognized, purpose of evaluation is that of supplying recognition of and reward for good instruction. For reasons which have already been developed, some of the more satisfactory means of evaluation of instruction are usually ignored, and frequently the whole matter of evaluation is ignored until a situation arises in which an individual is to be considered for a promotion, for permanent tenure, or for release. At this point, department heads and other administrative officers display concern as to whether the individual is a good or a poor teacher. The evidence available is usually entirely subjective. The opinion of the individual directly concerned is rightly regarded with suspicion, for the instances on record of professors publicly acknowledging that they are mediocre or poor teachers are not sufficient in number to generate any confidence in professorial objectivity on this matter. The appraisal of peers and that of administrators, too, is likely to be based upon casual student comment or complaint and , not infrequently, upon the displayed interest of the individual in matters related to teaching. Indeed, it is not improbable that an individual, simply by talking frequently and at length about the marvelous things that happened in his classroom, may convince his associates that he is an outstanding teacher. In the face of this situation, all too frequently the attempt to evaluate teaching in connection with promotion and financial increments ends up by being nothing more than an attempt to find out whether an individual's teaching is so bad that promotion or salary increase must be refused. Accordingly, there is generally no confidence in faculty members that really outstanding teaching will receive adequate recognition. Indeed, there is more than a suspicion that any review of teaching competencies will be solely to determine those who are inadequate in this regard. A continuing program of evaluation, not always and obviously related to tangible reward, will help to mitigate this suspicion. To be effective, such a program must be initiated and maintained by the faculty. Much of the failure of administrative officials to give appropriate attention to good teaching arises out of the failure of the faculty to provide evidence on this point.

A second purpose of evaluation of instruction is that of improvement of instruction. Studies conducted for this purpose may involve several groups with somewhat different patterns of experience and the systematic collection of data for statistical comparison and decision. Much of the evaluation of instruction which is carried on in the context of improvement represents an action research type of program. This differs from the controlled experimental design in that, rather than setting up contrasting patterns which are to be rigidly maintained over a period of time and compared in efficacy on the basis of statistical tests, the program of study may involve only one group. In action research, findings and experiences at any stage in the evaluation commonly bring about changes in the attitudes and viewpoints of both teacher and student, with the result that the forms or patterns of instruction which were initially to evaluate the development of students with regard to certain objectives may lead to the insight that the objectives are not intrinsically a part of the curriculum and instructional program. The experiences and materials developed for purposes of evaluation may be consciously turned to use in modifying instructional practice. In any case, the attitudes and the experiences of the teacher which result from developing the evaluation materials are very likely to modify the point of view and the instructional practices of the teacher in the classroom.

If an environment can be cultivated in which teachers feel free to try out new ideas without fear that failure will jeopardize their future, and with assurance that the extra time spent will be appreciated by colleagues and superiors, it can be expected that much more in the way of actual improvement of instruction will take place than when evaluation is administratively initiated, with the major purpose being that of making a decision about the continuation or promotion of the individual.

The third purpose of evaluation of instruction is that of research. Despite the very extensive research carried on in this field today, there is little that emerges in the way of definite conclusions. Any attempt to study instruction in an effort to define the approaches or qualities that make for success must recognize that instruction is a complex of many variables. The purposes and content of a course are obvious first factors. A course which is taught primarily to develop knowledge and understanding of certain subject matter presents a different problem than a course which is concerned with the cultivation of attitudes and values or of insights growing out of discussion and experience. The teaching of calculus can hardly be expected to be approached through a group dynamics approach, although this may be very appropriate in some of the social sciences. The personality and characteristics of the instructor are strong determiners of the success of the techniques used by that person. Some individuals are capable lecturers, but very poor discussion leaders, and others are examples of the converse.

The characteristics of students and their backgrounds must be considered in determining the patterns of instruction. There is enough research to suggest that certain types of students do not appreciate a discussion approach and are inclined to feel that it is a waste of time. Other students are found to do better in mastery of content and show increased growth in other objectives when discussion techniques are used.

The type and size of the classroom available and the general campus environment may result in what would otherwise be a very excellent instructional technique turning out to be quite inadequate. Thus, for example, in a multiple section course in which a common final examination is used as the primary determiner of the grade, an individual teacher who wished to instruct on a non-directive basis, whereas all of his associates operated on a lecture approach, would likely find such student resentment of his practice that he would be forced to change. The last example points up the fact that the evaluation practices are interrelated with the instructional practices.

When one considers, then, the range of factors operating on the determination of the quality of instruction, the difficulty of taking cognizance of all of these, and the further problem that the very active research on them changes the nature of some of the factors, it can readily be understood why research has yeilded so little. We tend to seek for broad global generalizations -- that one type of instructional technique is better than another. Thus, individuals have attempted to demonstrate that discussion is better than lecture, or that closed-circuit television is just as effective as small-group instruction. Even if such broad generalizations can be achieved on a 51-cases-out-of-a-hundred basis, they would provide very little guide as to what should be the instructional practice of a particular instructor in a particular class in a particular field in a particular institution. We must learn to seek for generalizations of lesser scope. These may take the form of a statement that, in the social sciences where certain objectives are involved, the discussion method seems to be superior to the lecture method. It may even be necessary to add further qualifications in regard to the type of teachers, students, and campus environment.

Review of the research done in the past on instructional techniques yields only a few generalizations. For example, we can conclude that it is possible to use group centered instructional techniques with just as much gain in mastery of content, and somewhat more gain in respect to other objectives, than is achieved in the more directive or lecture techniques. This generalization indicates that out of many such studies this usually has been the result. On the other hand, there have been cases of the other kind. From the reporting of such research, it is usually impossible to know exactly what transpired in the two different methods of instruction and, therefore, it is impossible to know just what factors may have led to the differences in findings. The fact that, in some one comparison of two instructional techniques, one group did as well or better on content objectives and better on certain other objectives, at least indicates the possibility that this result can be achieved. To go any further and say that this would always be the case is certainly inappropriate. It may be that, in the future, we shall find ways to describe in sufficient detail the nature of learning experiences and adequate means of evaluating changes of individuals in regard to a range of objectives so that more broadly applicable generalizations will emerge. There will never be a single prescription for good research. Yet differences do exist and they are distinguishable if we apply the principles and ideas earlier presented.

5. The Improvement of Instruction

Of the three purposes just discussed, it must be clear that the prejudice of the writer is that evaluation of instruction should be primarily oriented to improvement. This seems to be particularly important at a stage when we are trying to excite a concern about the quality of instruction. As has been pointed out, this is a very tender area with faculty, and the announcement of an attempt to evaluate instructional practices for purposes of reward is all too likely to cause defensiveness rather than a serious attempt to improve. Furthermore, evaluation applied from sources external to the instructional process must be very limited in nature. In the long run, the continuing attempt of a faculty to improve instruction and the insights that emerge from it, will develop an atmosphere in which better and more extensive evidence on the quality of instruction will be available for recognition and reward. Indeed, such reward must be forthcoming else teaching will be sacrificed to something for which the reward is evident. Improvement and reward are really but opposite faces of the same coin; neither can proceed without the other. Good instruction depends upon curriculum organization and the facilities available. It depends upon objectives, upon methods and materials, and upon how these are organized and interrelated. Furthermore, there is no end to the problem of evaluating and improving instruction, for there are no final answers to be found in terms of methods; new materials and new ideas are always accumulating to be woven into a course. At any time in which a teacher sinks into a stereotype in his instruction, both personal and student enthusiasm disappear and teacher effectiveness will diminish with it. Nevertheless, the teacher who is very much interested in students, and particularly in individual students, will find that teaching is a continuing challenge. To develop the reputation of being a good teacher, to be so regarded on a campus by the students, and to have one's course sought for on these grounds, is a satisfying experience, but it is not enough if the monetary rewards and promotions go to others who are indifferent teachers. We must recognize and reward good teaching if we are to maintain and increase interest in it in our colleges and universities.

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M-20

STUDENT OPINIONNAIRE

Major__________________ Sex__________ Class__________ Grade Point Average______

Directions: It is the desire of your instructor to continuously improve the instructional program. To accomplish this purpose, a systematic poll of student opinion is sometimes helpful. Carefully consider each question, then write a thoughtful, sincere response. Draw a circle around the appropriate rating in each of the "b" items. Do not write your name on this paper - your responses have no effect on your grade.

---

1. a. As you now see it, what is the most important purpose of the course other than receiving credit?____________________

   b. How well was this purpose met?

   Excellent   Very Well   Fairly Well   Poorly   Very Poorly

2. a. What course activity (lecture, lab., demonstration, etc.) contributed most toward the accomplishment of the above purpose?____________________

   b. How well was this activity carried out?

   Excellently   Very Well   Fairly Well   Poorly   Very Poorly

3. a. What method of study did you find most necessary to meet the grading requirements of this course?____________________

   b. How do you rate this method in terms of its general value?

   Excellently   Very Well   Fairly Well   Poorly   Very Poorly

4. a. What important plan, decision, or course of action are you considering as a partial result of taking this course?____________________

   b. To what extent did the work in this course influence this consideration?

   Almost Entirely   To Large Extent   To Some Extent   Little   Very Little

5. a. What is the most important action the instructor should take to improve the course?____________________

   b. In order to keep student interest and effort at a high level, how important is it that the above action be taken?

   Of Slight Importance   Fairly Important   Important   Quite Important   Very Important

6. If you have any additional comments to make concernig the course, the instructional technique, or the instructor, please state them below or on the reverse side of the sheet.

M-21

Michigan State University
TEACHER EVALUTION SHEET

Major_______________ Sex______ Class______ Grade Point Average_____________

Directions: It is the desire of your instructor to achieve the best possible instruction in this course. To help accomplish the purpose, this evaluation sheet was devised to obtain a systematic poll of student opinion. Carefully consider each question, then record your judgment by encircling one of the letters A, B, C, D, E, for each item. A blank space has been provided at the end for adding comments you wish to make

	A	B	C	D	E
1. Were important objectives met?	The course is an important contribution to my college education		Contributes about as much as the average college course		This course doesn't seem worthwhile to me
2. Does instructor's presentation of subject matter enhance learning?	Presentation very meaningful and facilitates learning		Presentation not unusually good or bad, about average		Presentation often confusing; seldom helpful
3. Is instructor's speech effective?	Instructor's speaking skill concentrates my attention on subject		Speech sometimes invites attention on speaker rather than subject		Speech usually distracting, concentration very dificult
4. How well does the instructor work with students?	I feel welcome to seek extra help as often as needed		I feel hesitant to ask for extra help		I would avoid asking this instructor for extra help unless absolutely necessary
5. Does the instructor stimulate independent thinking?	Instructor continually inspires me to extra effort and thought beyond course requirements		In general, I do only the usual thinking involved in the assignments		I seldom do more than rote memory work and cramming
6. Do grading procedures give valid results?	Instructor's estimate of my over all accomplishment has been quite accurate to date		Instructor's estimate of my accomplishment is of average accuracy		I feel that the intructor's estimate is quite inaccurate

(con't)

(con't)

	A	B	C	D	E
7. How does this instructor rank with others you have had?	One of the best instructors I have ever had		Satisfactory or about average		One of the poorest instructors I have ever had

Comments:

(favorable)

(unfavorable)

M23

REPORT ON INSTRUCTION

INSTRUCTOR COURSE MONITOR

LESSON TITLE

PLACE TIME DATE

RATING ITEM	RATING
PREPARATION	
Instructor Lesson Plan (Format and Organization)	
Evidence of Thorough Planning	
INSTRUCTOR QUALITIES	
Appearance	
Self-confidence	
Enthusiasm	
Body Vitality	
Contact with Class	
Voice Variety	
Speech	
PRESENTATION	
Introduction	
Logical Development	
Explanation	
Teaching Aids	
Checked Student Understanding	
Questioning Technique	
Student Participation	
Class Management	
Summary	
CONTINGENT ITEMS	
Demonstration and/or Practical Exercises	
Next assignment	

1. SCORE (Sum of ratings) __________
2. NUMBER OF ITEMS RATED (do not include "n's" __________
3. PRACTICE TEACHING GRADE (1 ÷ 2) __________

RATING CODE

N - Not applicable	
0 - Absent	Item was absent and should have been present.
1 - Poor (F)	Item was present but to know degree of satis-
2 - Below Standard (D)	Item was present to some degree of satisfaction but did not meet minimum standards of the course.
3 - Fair (C)	Item met minimum standards of the course but there is definite need for improvement.
4 - Good (B)	Item was handled in a generally competent manner and no major deficiencies were noted.
5 - Excellent (A)	Item was handled in a highly effective manner and deficiencies, if any, were of a very minor nature.

M24

NARRATIVE REPORT

In this space state briefly in the appropriate spaces particularly effective or ineffective elements noted and specific suggestions or recommendations for improvement.

1. Effective Elements:

2. Ineffective Elements:

3. Suggestions or Recommendations:

CHECK LIST FOR USE WITH REPORT ON INSTRUCTION

This check list provides specific criteria upon which to base the evaluation of each of the 20 Rating Items. Its purpose is to assure objective grading by users of this form.

PREPARATION

1. Instructor Lesson Plan
   a. Format (heading-introduction-development-summary-marginal cues-legibility)
   b. Organization (sequence-completeness)

2. Evidence of Thorough Planning
   a. Time-material relationship
   b. Conformity with lesson plan
   c. Continuity (smooth transitions pointed to objective)
   d. Subject matter adequacy

INSTRUCTOR QUALITIES

3. Appearance
   a. Neatness (dress-person)
   b. Bearing (carriage-behavior-posture)
   c. Mannerisms (unique action or style)
   d. Facial expression

4. Self-Confidence
   a. Composure (not agitated or disturbed-unperturbed)
   b. Positiveness (definite-sure of self-forceful)

5. Enthusiasm
   a. Animation (appearance of spirit and vigor-expressiveness)
   b. Sincerity (personally interested)

6. Body Vitality
   a. Descriptive gestures
   b. Appropriate gestures
   c. Purposeful movement (aimed-reasoned)

7. Contact with Class
   a. Rapport (accord-harmony)
   b. Friendliness
   c. Eye contact
   d. Humor (good nature)

8. Voice Variety
   a. Pace
   b. Pitch
   c. Volume
   d. Projection
   e. Emphasis

9. Speech
   a. Vocabulary on class level
   b. Effective grammar
   c. Articulation
   d. Pronunciation
   e. Enunciation
   f. Fillers
   g. Fluency (smoothness)

PRESENTATION

10. Introduction
    a. Tie-in (relates to other presentations)
    b. Objective (completely stated-definite)
    c. Why (purpose for lesson-student need)
    d. Motivator (interest arouser-appropriateness)

11. Logical Development
    a. Orderly sequence
    b. Transitions from point to point
    c. Developed from known to unknown and from simple to complex

12. Explanation
    a. Clarity of terms
    b. Completeness
    c. Meaningful examples
    d. On student level

13. Teaching Aids
    a. Appropriateness
    b. Number
    c. Type
    d. Size
    e. Timeliness in use
    f. Clear explanation of aid
    g. Relates talking to aid

14. Checked Student Understanding
    a. Allowed time for student
    b. Tested student comprehension
    c. Clarified misunderstandings
    d. Acceptance of student questions

15. Questioning Techniques
    a. Clear and concise
    b. Covers one point
    c. Adequate buildup
    d. Thought provoking
    e. Purposeful (aimed-reasoned)
    f. Required definite answer
    g. "ask, pause, and call"
    h. Acknowledgement of responses
    i. Follow-up techniques

16. Student participation"
    a. Distribution of responses
    b. Voluntary participation
    c. Participation pertinent to objective
    d. Student interest

17. Class Management

    a. Tact
    b. Control of physical facilities
    c. Enforcement of class policies
    d. Command of class situation
    e. Critique
    f. Timing of lesson

18. Summary

    a. Re-emphasis of main points
    b. Relation of lesson to subsequent lessons or activities
    c. Conclusions of lesson

CONTINGENT ITEMS

19. Demonstration and/or Practical Exercises
    a. Well-planned
    b. Properly introduced
    c. Accurate and realistic
    d. Well-paced
    e. Coordinated with expla-
    f. Clearly seen by all
    g. Logical sequence
    i. Reaches objective

20. Next Assignment
    a. Well-planned
    b. Properly introduced
    c. Clearly explained
    d. Related to present and person's work

CLASS VISITATIONS

Walter G. Whitman

Massachusetts Institute of Technology

Your request that I outline my views on "How can we evaluate teaching by class visitations" is probably based on Professor Sherwood's reference to my sporadic visits to recitations and lectures conducted by our staff members. As I think this over I realize that my purpose is not to evaluate the teachers but, rather, to observe and subsequently offer personal comments to the individual which may give him more reassurance on techniques which seem to be good and may call his attention to possible improvements.

The procedure is simple and personal. I tell the staff that I would be glad to attend one class of each member during the term if they so desire: that I will merely sit in the room, as unnoticed as possible, and will subsequently discuss my impressions with the instructor. Everyone agrees, of course, and I try to cover everyone--senior as well as junior staff. I always get the instructor's approval as to which class I should attend--practically, this means my proposing a convenient date and his concurring or suggesting some other time.

Most of the students are conscious of my presence as the class begins, and I realize that some of the instructors are somewhat affected by it. After the first ten minutes or so they generally forget that I am there.

The nature of the follow-up discussion with the instructor is perhaps best indicated by brief notes which I make during the class and then bring up in our discussion:

A. (junior staff) Compressible flow - nozzles - sonic and supersonic. Approach primarily mathematical, but with some physical picture - what would happen if you tried the reverse procedure? Board writing very clear, but could be more efficient on board space and avoid need for haphazard erasure. Good contact with class. Several in class were alert with good questions - you fumbled a bit.

B. (junior) Vapor-liq. equilibria (hot, humid afternoon). I'd guess half the class "fell off" after the first 25 minutes. Weren't you repeating material that's in the book, which they should get by outside study? Voice - clear, but too loud (metallic), too fast, too excited. Board work clear and efficient. You belabored points which the class understood. - Study student reaction!

C. (senior staff) Polymers lecture. Excellent - and got good student participation for a class of 60. Only suggestions: (1) your term "energy dissipation" was a bit cloudy - only later did you differentiate clearly between "generation" and "dissipation". (2) give some actual temperatures and BTU's in a specific case.

D. (junior) Polymers - review of Quiz. Could you let students go further in answering a full question? Admittedly, your technique allows (1) more chance to explore other facets, (2) you can cover the Quiz in the hour, (3) more instruction on the subject. Very good session - voice good - board work good - fine comprehension and lucidity - you know your students.

E. (senior) Lecture to sophomores - Combustion. Your main objective seemed to be exciting the student about the beauties of research. Quite effective - class attentive. I felt at the time that you included too many new terms and ideas and also that it might be too exotic at this stage - but I'm not sure now. Voice - rather low, but clear enunciation and clearly understandable from last row. You seriously overran time and students got nervous about next class.

F. (junior) Thermodynamics. Good voice and manner - excellent rapport with students. Stimulated class discussion (14 men). You seemed technically a bit hazy about the ram-jet problem. Could be a bit neater on board work. Don't these problems involve too much "trade jargon"?

G. (intermediate staff) Diffusion - Lecture to Faculty. Interesting and dramatic, but you were a bit nervous before this senior audience. Explosive delivery, followed by "asides" which were too fast and too low. In your enthusiasm you overstate, e. g. "overwhelming mass of data". Don't leave your slides on so long - call for room lights earlier. General appraisal - very good.

H. (intermediate) Industrial Chem. Good condensed presentation, but I fear you put in too much material and detail for this lecture. A little more general principles - less specific practice. Explain about "yields"? Occasionally your voice runs off in a minor clause. If it's worth saying, make it intelligible to all.

I. (intermediate) Combustion problem recitation. A very interesting hour, with good elucidation. You tried to cover too much, I believe. Did you want to prove that the gas analyses were wrong? You did that, all right, but you needed more time then to discuss the probably reliability of the conclusions. The problem is a bit forced, because an experienced engineer would have obtained one more piece of data which would have been decisive. Good rapport with class - dynamic.

J. (junior) Thermo quiz discussion. Good active presentation and discussion. You worked a bit too fast on that "short cut". Board work generally good, but a few figures too casual. I particularly liked your asking whether the class had "any questions" after the problem was apparently finished - waiting for the key Q. which didn't come - and then posing it yourself to a student.

K. (junior) Radiation. Good voice and board work - and questioning of class. But the class (and you?) were pretty confused in the last 15 min. Perhaps, with more study, you can clarify and convey a simpler generalization.

L. (intermediate) Fugacities (class of 60). Good impression thru the hour, except that voice level was marginal (from back row). Fine class interest. I wonder whether the "elegance" of the development is warranted (agreed later that it was). Handled the few questions ably.

M. (senior) Fluid Dynamics. Superlative. Your outline of the program for the rest of the term (1st 20 minutes)gives perspective. This class of 60 is too large for much student questioning. I'd like to attend a "recitation" class as well.

MM4

N. (very senior) Students intent and interested. Hard to understand when you speak in lower register - a rumble. Much clearer when voice is raised.

O. (senior) Indust. Chem. A live class, which participates well and enjoys your friendly, humorous provocativeness. When a student elects to pick an awkward basis for solving a problem you cooperate with him to just about the right degree - then you drop it when time wastage threatens. Allow a bit more time for the qualitative discussion? (I find that it will be taken up at next class.)

P. (senior) Kinetics. Small class (sub-standard?) The problem was excellent, but poor student participation. Why aren't the students prepared, by outside reading and working on the problems?

Q. (senior) Chemical Kinetics - discussion of Quiz - small group of very able seniors. Very stimulating discussion (in fact, I broke my rule and entered it). Voice and manner excellent. I liked your insistence on "What facts can you point out from the data". A good problem for exploring other interpretations objectively and showing their inadequacies. Well done. Only suggestion: I thought that 2 of the students (A and B) gave clear, brief answers. Perhaps you should have given them credit before you summarized yourself.

THE TEACHER--DEVELOPER OF PROFESSIONAL CONSCIOUSNESS

Cornelius Wandmacher
University of Cincinnati

1. Assuming the Teacher's Responsibility

When we begin to discuss matters of developing professional consciousness in students, the suggestion which most frequently comes to mind is this: "Yes, indeed, we ought to have a course to cover that!"

Conducting a course under this or that title is a natural and in some ways an effective means of presenting material of an informational character. It is even an acceptable way of presenting ideas. But attitudes, such as those of professional consciousness, may best be inculcated by a constant process of osmosis operating in many places at many different times. Such a task should not depend on a single teacher who happens to have the responsibility of a single course. The task of establishing professional attitudes should be the everyday assignment of all teachers who have the responsibility collectively for the total education of young engineers.

Let us not rule out entirely the value of a course dealing with professionalism, but let us concentrate primarily in this discussion on how each and every one of us at various times shall seek out, recognize, and capitalize on the opportunities which come to us, sometimes unexpectedly.

In short, there are two fundamental professional obligations every engineering teacher needs to fulfill:

1. To be well informed on the heritage of engineering as a profession, and on recent progress in the better identification of the profession.
2. To emit personally at all times an exemplary attitude so that he may imbue professional attitudes in his students even as he goes about the tasks of teaching in subject matter fields.

The major part of transfer of a professional attitude should come as a result of a conscious effort on the part of the teacher, but his own attitudes should be so well developed that there will be transfer even unconsciously at times unplanned for. Sometimes these latter incidents are of greatest impact on the student.

Perhaps the best authority to quote in this matter concerning personal responsibility is the ECPD statement known as the "Faith of the Engineer." It reads as follows:

> "I AM AN ENGINEER. In my profession I take deep pride, but without vainglory; to it I owe solemn obligations that I am eager to fulfill.
>
> As an Engineer, I will participate in none but honest enterprise. To him that has engaged my services, as employer or client, I will give the utmost of performance and fidelity.
>
> When needed, my skill and knowledge shall be given without reservation for the public good. From special capacity springs the obligation to use it well in the service of humanity; and I accept the challenge that this implies.
>
> Jealous of the high repute of my calling, I will strive to protect the interests and the good name of any engineer that I know to be deserving; but I will not shrink, should duty dictate, from disclosing the truth regarding anyone that, by unscrupulous act, has shown himself unworthy of the profession.
>
> Since the Age of Stone, human progress has been conditioned by the genius of my professional forbears. By them have been rendered usable to mankind Nature's vast resources of material and energy. By them have been vitalized and turned to practical account the principles of science and the revelations of technology. Except for this heritage of accumulated experience, my efforts would be feeble. I dedicate myself to the dissemination of engineering knowledge, and especially to the instruction of younger members of my profession in all its arts and traditions.
>
> To my fellows I pledge, in the same full measure I ask of them, integrity and fair dealing, tolerence and respect, and devotion to the standards and the dignity of our profession; with the consciousness, always, that our special expertness carries with it the obligation to serve humanity with complete sincerity." (1)

Note particularly the underlined phrases. Surely this is the responsibility of all engineers but mostly the obligation of engineering teachers to those who are their students.

2. Establishing the Heritage and Background

Much of the "Faith of the Engineer" reflects on the "heritage" of engineering. It might well be asked: "Does this come under the heading of effective teaching?" Yes, indeed, since our total objective is to teach in a manner which will educate professional men.

To do this successfully we must instill in our students a sense of pride in the profession for which they are preparing. To have pride in the profession they must understand its heritage.

What is this heritage? Perhaps the best available discussions of this topic are in "A Professional Guide for Young Engineers" by William Wickenden (2) and throughout "Your Approach to Professionalism" by N. W. Dougherty (3).

First, it seems important to establish firmly in the mind of each student facts about the place of engineering in modern society: How society has moved from an economy where each man worked and lived principally with his own possessions to a point where every man now has vast facilities at his disposal; how strikingly the amount of energy available per worker has increased; how much improved conditions of sanitation, transportation, and communication have given man the chance for an enriched life. There are many ways each instructor can substantiate these facts. It may also be pointed out that the engineer has a unique opportunity to contribute to society on the basis of things which will count in the advancement of human welfare.

Secondly, it needs to be established, for instance, that there was a day when there were no methods of stress analysis, when structures and machines were built almost entirely by experience and a sense of proportion. The story of evolution of present day engineering methods can be a constant source of inspiration. In the words of Wickenden (2):

> "Without what countless men, most of them unnamed, have contributed to the building of knowledge and technique, to the accumulation and testing of experience, to the formulation of safe rules of practice, and to the organization of united effort, one could never practice a profession at all. These gifts from the past are not a private right, but a social trust."

Thirdly, there is a constant need to reaffirm that if there is any secret of success behind the "engineering method" it is good team work. Again to quote Wickenden (2):

> "There have been geniuses here and there who made epochal contributions, but the essence of modernity is that progress no longer waits on genius; instead we have learned to put our faith in the organized efforts of ordinary men. Organization is simply the means by which the acts of ordinary men can be made to add up to extraordinary results. To this idea of progress that does not wait on some lucky break, some chance discovery, or some rare stroke of genius, but instead is achieved through systematic, cumulative effort, the engineer has contributed brilliantly. Among the professions, engineering is the exponent of organization, par excellence."

This aspect of our heritage also is a chance to point out that engineers as team workers must be prepared in the words of Huxley to deal with "men and their ways" as much as with "things and their forces."

Perhaps this is the juncture at which to accentuate the concept that in engineering education there is much beyond mere technical training.

Fourth, engineering students at all stages can profit by repeated discussion of the following "Characteristics of an engineer" introduced in the Guide (2):

*Courage and Integrity - Engineers must take calculated risks and make decisions on the basis of incomplete information. Shoddy work will not do where human lives and heavy investments are at stake. Engineers deal with the laws of nature. These laws are fixed and inescapable. The engineering practitioner, therefore, must be rigorously honest in thought and in action; no amount of brilliance will enable an individual dealing with such matters to ignore or to attempt to distort even the simplest laws of nature. Engineering has no place for men who are merely smooth or clever. Clever argument and disputation may not be substituted for the integrity which an engineer must possess.

Imagination - A strong native sense of quantity and form, may be called the conceptual factor most vital to successful engineering. Students should be apprised of the requirements to think in dimensions, magnitudes, ratios, percentages, roots and powers; to "see things in the mind's eye," and to visualize them as they would be in actuality.

Sound Judgment - The capacity for sound judgment enables the engineer to differentiate between feasible projects and mere speculative promotion; between the solution of a problem and the covering of an undesirable situation by deception or strategem; between the rendition of a service to humanity and the acquisition of mere personal glory; between ethical conduct and chicanery.

Accuracy - It may be said with considerable emphasis that engineering should not be undertaken by persons of careless or casual traits. Accuracy in thought not only ferrets from the daily welter those tasks, which are essential to the objective in hand, but it likewise makes possible the technically dependable and economically sound solutions which are required to convert ideas into worthwhile realities.

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*These itemized statements of characteristics are selected and adapted from those found in the Guide (2).

Instinct for Economy - There is a distinction which must be discerned between cheapness and economy. In an engineering project, it is not necessarily the cheapest way of doing it that is of paramount importance, but the way which will produce the most effective results or the largest useful return for the money and effort expended.

The Habit of Thinking Back from Effects to Causes - Successful engineers exhibit the inherent natural trait of looking behind a manifestation to determine its cause. This characteristic may be described as thinking in terms of functions. It requires inductive ability.

Ingeniousness is the characteristic for which engineers are named. Without ingeniousness, the fabric of which engineering is composed would literally be reduced to unwoven threads. Practitioners who are able to take commonplace situations and apply imagination of conception and ingenuity to produce and improve results are the ones who contribute great benefits to mankind.

Ability to Think Lucidly - It is quite obvious that the engineer must be able to think in orderly fashion, to break his complex problems into small units which can be solved, to select and apply the requisite reasoning and principles.

It is here that we should stop to note that a course in professionalism as such can at best identify and enunciate these characteristics of engineering. But there are abundant instances in all subject matter courses where real illustrations which vividly demonstrate these characteristics may be found. This is an area in which engineering education is usually quite weak. This is an area of great opportunity for the teacher with a professional consciousness.

Note especially that it is not necessary to enumerate all of these characteristics at a particular time. Rather it is well to take one of them at a time and illustrate it conclusively in accordance with the subject matter at hand.

There are, of course, a number of other characteristics which might be mentioned, such as: thirst for knowledge, aptitude for leadership, and capacity for hard work. These are important but seem less exclusively the characteristics of engineering. The latter is perhaps the most admissable especially as a requisite for engineering students.

Finally there is the concept of the engineer as a student. As an undergraduate the engineer has an excellent reputation. It is well to challenge all engineering students to strive to maintain the standards of the group into which they have been accepted.

These factors might well be introduced in a course in "Professionalism" but it behooves all engineering teachers to reinforce the images and concepts developed therein. In all courses we need to demonstrate, to elucidate, to cite instances and examples wherever and whenever we can.

3. Identifying Outstanding Engineers and Important Engineering Works

To know a profession is to know its men of stature and its monuments of achievement. It behooves all of us, therefore, to take the initiative in identifying for our students outstanding engineers and describing their contributions to the growth of the profession. Likewise, it behooves us to take the initiative in identifying for our students outstanding engineering projects and in describing their significance as milestones in engineering.

There is a long list of such examples which comes to the mind of each of us as examples of the above categories. Rather than list names at this point, let us discuss a few aids which may be helpful in presenting such material.

1. A few years ago a group at the University of Illinois brought together a unique collection of photographs of nearly 200 renowned engineers. These are available for reproduction, framing, etc. Such photos may well be used to enhance the discussion and presentation of biographical sketches of outstanding engineers.

2. Recently the American Society of Civil Engineers has had conspicuous success with the selection of the "Engineering Wonders of the Modern World." This program has been carried out at both the community level and at the national level. It sets a fine example of what may be done in calling attention to outstanding engineering works.

3. Each year every engineering society presents a number of awards and prizes. One very productive activity for engineering students is to have them discuss the papers or works of those so honored and also their biographies.

4. Present day youth generally gives insufficient attention to biographies of great men. It is an interest which needs encouragement and nurture. Interesting our students in biographical works may lead both to a better understanding on their part of the engineering profession and also to a sounder interest in good reading. Biography of forbears may be a source of almost unbounded stimulation for career-minded youth.

4. Defining Engineering and Describing a Profession

A study of the definitions of engineering is an intriguing study in evolution. From the early Treadgold definition to the most recent official ECPD definition is a major story in the growth of the profession.

In 1827, Treadgold held that: "Civil Engineering is the art of directing the great sources of power in Nature for the use and convenience of Man, as the means of production and of traffic in states both for external and internal trade, as applied to the construction of roads, bridges, aqueducts, canals, river navigation and docks, for internal intercourse and exchange, * * *, and in the construction and adaptation of machinery and in the drainage of cities and towns." (See p. 257, Journal ASEE)

Note that at the time "Civil" was the only recognized branch of what we know today to be the broad field of engineering.

The ECPD Recognition Committee (4) suggests: Engineering is the learned Profession in which a knowledge of the mathematical and natural sciences gained by study, experience and practice is applied with judgment to develop ways to utilize, economically, the materials and forces of nature for the progressive well being of mankind.

Incidentally, this Committee also suggests very seriously that consideration be given to changing the designation "Engineer" to a more appropriate or meaningful title. The results of considerable research on this topic appears in the 1958 Annual Report of ECPD.

A challenging study of definitions of engineering was done by Professor Herbert J. Gilkey (5) who presented 8 such definitions. Here is an abundant font of material for many fruitful hours of formal or informal discussions with engineering students.

Gilkey suggests the following brief factual definition: "Engineering is the application of science and art to the economic utilization of materials and forces in conjunction with the organization and direction of essential human skills."

Gilkey's main contention is that the ECPD statement is a "dissertation on professionalism" rather than a simple definition of engineering. That's his opinion; what's yours? What do you think the consensus of your students would be?

When it comes to describing the attributes of a "profession" there are perhaps as many divergent points of view as in the definition of "engineering." However, certain broad characteristics of a profession have been fairly well agreed upon and are discussed fully in the works of Wickenden (2) Dougherty (3) and others. These generally accepted attributes of a "profession" are that it is a "calling" which:

1. Renders a specialized service based upon advanced specialized knowledge and skill, and dealing with problems primarily on an intellectual plane rather than on a physical or a manual-labor plane;

2. Involves a confidential relationship between a practitioner and a client or employer;

3. Is charged with a substantial degree of public obligation, by virtue of its possession of specialized knowledge;

4. Enjoys a common heritage of knowledge, skill, and status to the cumulative store of which professional men are bound to contribute through their individual and collective efforts;

5. Performs its services to substantial degree in the general public interest, receiving its compensation through limited fees rather than through direct profit from the improvement in goods, services, or knowledge which it accomplishes;

6. Is bound by a distinctive ethical code in its relationships with clients, colleagues, and the public.

In this list you will also recognize the opportunity for many different points of discussion which can be drawn upon when the opening occurs for authentication in a broad range of regular class situations.

5. Being Literate in Professional Literature

All of the preceding comments suggest a vast storehouse of material must exist on the heritage and background of the engineering profession. Where is the best place to get an overall look at what is available?

An excellent reference for this purpose is a bibliography entitled: "An Engineer's Library - Guide to the Profession" (6). A few of the titles suggestive of the scope of the list are:

A Hundred Years of Mechanical Engineering - Edward Cressy
Engineers and Ivory Towers - Hardy Cross
Engineering and Western Civilization - James K. Finch
A History of Engineering - Arthur P. M. Fleming & H. J. Brocklehurst
Engineers' Dreams - Willy Ley

Master Builders of Sixty Centuries - John A. Miller
The Engineer in Society - John Mills
Engineering the New Age - John J. O'Neill
A History of Civil Engineering - Hans Straub
Modern American Engineers - Edna Yost

The complete list of 32 books may appear formidable at first but two thoughts come to mind in respect to it: 1) See that a collection of these books is prominently displayed in your college library; 2) Select 4 - 5 books each year from the list, read two of them well, brouse in the others. Undoubtedly you eventually will have suggestions for additions to the list.

Of particular interest to teachers, and to students, should be the volumes dealing with the historical development of a branch of engineering or engineering science, such as mechanics or hydraulics. Available works in this field have improved in recent years both in quality and in quantity.

6. Knowing the Status of Engineering Education

Alert teachers are naturally aware of significant trends in their respective fields of education. As a member of ASEE, you regularly receive the "Journal of Engineering Education." It presents the current topics of discussion and is an excellent reference for keeping up to date.

Beyond this you will want to refer from time to time to some of the reports and evaluations of engineering education such as those made at the following intervals:

1958 - Report on the Engineering Sciences
1957 - Engineering Education and Training - A report to EUSEC
1956 - General Education in Engineering - A report of the Humanistic-Social Research Project
1955 - Report on Evaluation of Engineering Education
1952 - Report of Committee on Adequacy and Standards of Engineering Education
1950 - Differentiating Characteristics of an Engineering Curriculum (7)
1944 - Report of Committee on Engineering Education After the War
1940 - Report of Committee on Aims and Scope of Engineering Curricula

In addition it would be well to brouse in the Annual Reports of ECPD available in your Dean's Office or at Engineering Society Headquarters, 33 W. 39th Street, New York City.

Occasionally a direct quotation from one of these reports may furnish a springboard for a discussion with your students of the objectives of engineering education, for they too should have an awareness of the philosophy behind the curriculum. They, too, should be acquainted with the fact that you and your colleagues are constantly evaluating and re-directing the educational program with a positive, progressive approach.

One such thought provoking passage is the following adapted from the 1944 report (8):

The evolution of engineering thought and of engineering practice has given us a body of knowledge based upon facts and principles that may be classified in five broad categories.

1. Generic principles such as the basic concept of conservation of energy.
2. Basic assumptions (not always true but practically useful) which are made for the purpose of simplifying the mathematical analyses of physical phenomena, such as Navier's hypothesis that a plane section before bending is a plane section after bending.
3. Empiricisms, such as the properties of materials which have been observed and measured in the laboratory; also the whole host of coefficients and constants which we constantly apply.
4. Derived principles, or working formulas which have been developed in various fields of practice.
5. Specifications and standards or codes of practice, many of them having legal status as a result of public experience.

Imagine the discussion with students whach might ensue from an endeavor to cite examples which would substantiate or refute this statement in 1960.

7. Knowing the Status of Unity in the Engineering Profession

One goal which has received increasing attention in recent years is that of "unity" in the engineering profession - a move to increase the solidarity of the profession by consolidating in some way the many parallel and splinter groups which are found under the canopy of engineering--a move to identify the voice which may speak for all engineers.

To understand the problems of such consolidation, one must be conversant with the aims and activities at least of the following groups:

1. Founder Societies: ASCE, AIME, AIEE, ASME, AICHE
2. United Engineering Trustees
3. Engineers' Council for Professional Development
4. Engineers' Joint Council
5. National Society of Professional Engineers

The recent campaign for the new United Engineering Center, now being erected on the United Nations Plaza in New York City, has given many engineers a better understanding of the "Founder Societies" concept and the work of United Engineering Trustees. This new headquarters of engineering in America is now in itself a development which we should surely bring to the attention of our students at every opportunity.

Founded in 1932, the Engineers Council for Professional Development, has served eight major participating societies in numerous intra-professional matters such as: selection and guidance of students, accreditation of educational programs, post-graduate development of young engineers, development of the Canons of Ethics, recognition of the engineer and the profession.

Since 1944 the Engineers Joint Council has served a similar group of participating societies in inter-professional and public matters, now being the spokesman for the largest number of engineers in one general organization.

The National Society of Professional Engineers, which recently celebrated its 25th anniversary, is a rapidly growing organization. NSPE is probably best known for its work in the fields of: licensing, engineer-in-training activities, its firm stand on professionalism vs. unionism, and its intimate type of state and county organization throughout the country.

Undoubtedly, these organizations will come soon to a more unified type of structure. As teachers, we should be prepared to interpret for novitiates under our guidance, the plan for unity as it unfolds.

8. Having An Opinion on Unionism

For many years opinions of engineers wavered markedly in respect to unionization. There was a time in the early '40's when leading educators went so far as to say that being a member of a trade union might be a good experience for a young engineer, an experience he would not forget during the rest of his career.

What they failed to realize is that an individual cannot get in and out of a union at will; that the whole concept of union control is based on closed shop operation. To get men "in" under any circumstance is the objective of every union.

Some groups of engineers, notably those in large concentrations and generally those intermingled with a large number of technicians and tradesmen, have adopted union organization. In a number of cases in the past, trade or technicians unions have reached up and drawn engineers into a union with them. This situation has been largely corrected by federal legislation, but not without considerable effort by the profession.

In general, it may fairly be stated that currently there are more conspicuous cases of de-unionization of engineers than of new unionizations. Also engineers generally are taking a more positive stand that unionization is incompatible with professionalism.

In any case, an engineering teacher needs to be prepared to discuss this matter openly with his students. While it appears that engineering graduates presently show little interest in unionization at graduation, the external pressures may nevertheless increase. An occasional frank and open discussion of unionization at the student-faculty level will do much to prepare students for facing this problem when it arises.

9. Setting an Example Through a Personal Development Program

In the long run one makes more lasting impressions by what one does rather than by what one says. To put it another way, what one says is much more impressive if it is backed up by exemplary behavior.

For various reasons each instructor will want to have a personal development program of his own specifically related to the career he visualizes for himself. While the objective may be one's own development, it will be recognized that there are many unobtrusive ways in which the activities of such a personal program can be and are brought to the attention of one's students.

Another paper in this series will discuss the "First Five Years" program of ECPD for young engineers. For the particular guidance of young teachers, an enlightening paper is that of Dean Hazen entitled: "Letter to a College President" (9). Written for the purpose of explaining some accreditation philosophy in the matter of "What we look for in a faculty member," it nevertheless enumerates some sound policy for the young teacher contemplating growth through research, publication, advanced degrees, society activities, etc.

In any case, whether or not an instructor has a definite program for his own professional development will soon be apparent to one's students. A well conceived program will soon be admired by them.

10. Making the Most of Every Opportunity to Elucidate

As discussed at the outset, it is not the place of a single course in "Professionalism" to accomplish the task of developing a professional consciousness in our students.

It is a matter of each course being pervaded by an aura of professionalism which emanates from the instructor in that particular course.

In dealing with students, it is the little things in "asides" which sometimes count the most. Be prepared to make the most of such countless opportunities.

In the final analysis, remember that it is the posture, the bearing and the attitude of each instructor which will have the greatest impact on the professional consciousness of the engineers of the future.

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PROFESSIONAL DEVELOPMENT

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There are some basic differences between the collegiate world and, particularly, the industrial world to which a student could be introduced to advantage during his college career. Some of them will be mentioned in this talk; others will occur to many young engineering teachers who perhaps have had a little industrial experience or contacts with those who have.

It has been said that the half-life of an engineering education today is ten or fifteen years. This indicates that students must be prepared to take the initiative of keeping themselves up to date after they leave the confines of the college. His background during his college years has been that of a scholar interested in acquiring knowledge. The labels he is apt to put on activities are associated with that knowledge such as mechanical engineer, electrical engineer, etc., whereas in industry the label of sales engineer, design or production engineer may be much more significant.

It would seem apparent that most young engineers have a slight conception of what is need from them in their industrial life. It is to their credit that they learn it quickly, but it is also probable that a few are lost to the profession or, at least, have their development delayed. The question can be, "Can we save these people and can we hasten the development of all of them through engineering teachers giving them some better measure of understanding of industry during their undergraduate days?"

For a number of years the writer has asked each succeeding group of young graduate engineers who appear for industrial training if they are acquainted with the "First Five Years" program of ECPD. 10-20% will raise their hands without hesitation; perhaps another 10-20%, after checking with those adjacent to them to make sure what we are talking about, hesitently raise theirs.

This is not enough. Every graduate should have an idea at the time of graduation concerning the basic problems and opportunities which are going to confront him after he leaves school.

During the time a student is in college his hours are thoroughly occupied. He has much studying to do, and when he is not studying there are ample opportunities for enjoyable activities around any college campus.

He doesn't have to look for projects, entertainment, culture, reading matter, or anything else; it is there and by and large very satisfactory. Little decision has to be made concerning selection either. The mix is good.

After 16 years of being told what to do, of being judged on how well you do what you are told, and of being in a world where the pursuit and acquisition of knowledge is king, the student may be bewildered in arriving in a world placing considerable emphasis on other values.

The career of the student is orderly and predictable. He knows where he is supposed to be, when he is supposed to be there, and what he is supposed to do in considerable detail. His rewards in college are immediate and predictable. He knows if he works all the assigned problems right and he gets them in on time he gets an "A", and he gets it promptly. In industry, of course, this is not so. He does not immediately get a raise because he has done a good job or does he immediately get a promotion. There may be no money in the till and no higher spots to fill. When he takes a job his tasks are not predictable in the same sense that they are in school. He knows that in general he has to design, build, or apply a machine or device, or establish a service. But the problems in doing this successfully are largely measured by a P & L statement and not by the amount of knowledge he is able to acquire. How to achieve a successful P & L statement may involve technical skills, business skills, or skills in human relations, and it is not very clear which ones or in what proportions they are always needed.

The difficulties involved here and associated with the early years of the young engineer can be helped by a few discussions and some good hard thinking about the 6 points (First Five Years Program) of the Engineers' Council for Professional Development. These 6 points are:

1. Career Orientation
2. Continuing Education
3. Professional Identification
4. Responsible Citizenship
5. Selected Reading
6. Self-Appraisal

Career Orientation, the first one, involves how the student is going to get started successfully. Some students seem to find mild difficulty in understanding that a business institution is not a philanthropic institution--that everything it does must end up in profit eventually. The men who help him become acquainted with specific details usually have other jobs on which their progress in the company depends than the one of teaching him the ropes. It is important he understand that he has to find his own paths to the top and often his own means of being more than ordinarily useful.

One of the means of being more than ordinarily useful is to continue his education; but to a large extent he will have to establish what to study by himself--at least his responsibility in this regard will increase after he leaves college. Professors skilled in education will be more remote.

Certainly one of the easier ways to keep up in your profession is to be active in a professional organization. Papers, meetings, and contacts give one at least an outline of what is going on in his particular field. There is also a duty here--a duty to not only participate in discussions or provide an audience for others, but to help out with the housekeeping chores of meetings, membership, and finance.

It is interesting to note that a number of large corporations are beginning to stress the idea that their employees should be good citizens. This is a difficult concept for a corporation to present to its employees. It is hard to be nonpartisan on political issues, and to be effective without it is a real challenge for those responsible for the program. The basic idea that any corporation would like to have its employees be people of substance in their communities is a sound one. The young engineer just out of school has probably had little acquaintance with responsible citizenship and with civic, professional, and social activities in local communities. Somewhere along the line he has to learn what he can do--how he can help. It is also wise for his own development that he become a part of the community--to establish his clubs, organizations, hobbies, philanthropies, and get going on his life.

Most people like to read but they don't always get at it, and when they do they might pick up anything at hand. What we are going to read should legitimately be established on the basis of our particular kinds of interests and our personality. It would be too bad if we all read the same thing; but once you decide what kind of reading you want to do, why not read the best? How do you know the best? In the writer's own company we make a regular habit of passing out the folder "Selected Reading" to all engineering students. It is much appreciated by them. We think it is a good list--well catalogued.

Once a year, in the writer's company, we have a big banquet where all the young engineering trainees are assembled together with the "wheels" of the company. We call it a "Big Wheel-Little Wheel" banquet. We have a top executive speak. Interestingly enough, one of our recent speakers spent quite a bit of time suggesting that all of us in the company do a job of personal appraisal to see where we could make the greatest contribution/to see where our weaknesses were so that we could shore them up. Since his remarks fitted so well with the philosophy of the Personal Appraisal form gotten out by ECPD, we sent him a copy. He was much pleased and gratified to learn that an effort was being made along precisely the lines that he had independently conceived as being important to young men.

Matters pertaining to these 6 points pop up in many spots in industry. Young engineers are interested. A year or two ago a group of our young engineers came to me and wanted to set up a committee concerned with professional development. The seed may have been sown in some college due to the First Five Years program. In any event, they wanted to know, "What can we do in this field to help ourselves?" We had a ready made answer--the Engineers' Council for Professional Development's First Five Years program. We had literature to give them.

Our sales training people were interested in the extra-curricular activities of a salesman. What does he do to put himself in a position to better serve his customers. A useful area is certainly to help in the professional identification activities of his community. They asked the writer to give a talk on these extra-curricular activities revolving around professional and technical organizations and their place in an engineers life. We pointed out the need for our salesmen to know people and know what concerned their engineering community. We suggested they should be prepared to aid in securing speakers and preparing better and more useful programs.

We point these out to you to reassure you that the 6 points are down-to-earth, practical subjects which have an everyday value in an everyday world. Their implementation should be a commandment to all those responsible for the development of the young engineer. It is our experience that the young engineer will appreciate any efforts in his behalf. It is our experience that such an effort will be helpful to whoever promotes it, too.

RESEARCH IN ENGINEERING EDUCATION

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1. Why Research in Engineering Education

How are engineering courses taught today? How do the methods differ from those employed years ago? When changes in methods, curriculum and procedures have been made, was it known that the new methods were better than the old?

The American Society for Engineering Education, one of the few professional societies which is devoted to the education process as distinct from the knowledge of subject matter per se, was founded in 1892. In this period of over 60 years many good and important ideas have been advanced but is it known how good or how important these ideas have been? How many of the good ideas have been lost?

It appears that a large part of the engineering educational system operates as it did a hundred years ago, surely as it did thirty years ago. For the most part, an instructor meets a small group of students periodically in a room with a blackboard, and he and his students discuss certain subjects. The hours may be devoted to the solution of problems by the students, or to a vigorous discussion by the students and the instructor, or the instructor may do most of the talking, etc. This same instructor quizzes his students and determines their grade. Other instructors in the same or different schools may have entirely different methods for instruction on the same subject. They may even have different objectives; and, in general, they have different grading standards. It is quite likely that one of the learning situations is better than some of the others, if not better than all of the others. The words "learning situations" are used here to include the instructor, the atmosphere, and the methods; for the same methods and atmosphere may not produce the optimum result with a difference in instructors. Usually the results are not compared. When they are, the comparisons are not made in a quantitative way. Hence, it is not known which methods or procedures for instruction are best.

In the technical side of the subject materials and items of production are compared and tested. Measurements determine what materials are stronger, harder, more ductile, machineable, and under what conditions. On items of production, tests are employed to determine their efficiency of operation, their life, their conformance to standards, etc. In short, many physical tests are applied to determine the best products for particular purposes. Engineers do not stop there. They continually search for new materials and new design which in some sense, a measureable sense, will be better than the current ones. They not only apply these rigorous measures to inanimate things, they also apply them to motions and operations of individuals in the production process. For all of this there is a need for research, for measurements, and for testing. "Engineering is the professional art of applying science ---." Engineering changed from a pure skill or art when we began to accumulate information in a scientific manner. Thus, by the addition of the scientific aspects, the profession was strengthened.

Even though, as Dr. Ebel has told you, a lot is known about educational tests and measurements in engineering education, very few comparative measurements have been made. The knowledge is of qualitative nature. Changes have been based upon experience and judgment rather than science. Experience and judgment were the first basis of engineering and are still a fundamental part, yet studies have been more rapid since the inclusion of science. Engineering education, in a way, is still in the artisan age. If there is a storehouse of information on how best to carry out the function, much of it is passed from one to another in a similar way folklore of old were passed.

The very term engineering is almost synonymous with progress. It is often said that the history of engineering is the history of civilization and of this engineers are justly proud. Also, the growth of civilization has been closely associated with colleges and universities. These institutions have been looked to as the leaders in progress. Yet, the changes in methods and procedures for spanning the gap between instructor and learners at colleges and universities has in no way kept pace with engineering development in the past 6 decades. This development in the engineering areas has resulted from the application of a scientific approach: a research approach. It is time for the adoption of the scientific approach to engineering education, and the application of the techniques to the education process which have been so nobly applied in the realm of development and production. Some will say "This cannot be done;" "The techniques do not apply;" etc. The same arguments could have been given in other fields where the procedure has produced miraculous results. Try it before saying "It cannot be done."

These comments are not meant to be disparaging on the good work that has been done in the field of engineering education, but instead to point to the fact that in the area of education the experimental techniques have not been employed in the same rigorous manner as they have been in obtaining knowledge of engineering materials and products. The work has been more qualitative in nature than quantitative. This qualitative work is important. It is the beginning, but only the beginning. To quote from a lecture of Sir William Thompson of May 3, 1883, "I often say that when you can measure what you are speaking about and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind: it may be the beginning of knowledge, but you have scarcely, in your thoughts, advanced to the stage of science, whatever the matter may be." Surely this statement applies to the field of education.

This field of engineering education is big business. (Dean Teare has told you this.) There are 154 accredited colleges with 305,332 students. There are clear cut objectives; we should strive to find the best way to fulfill these objectives. Many people stress the need to know the best methods because of the demand for highly qualified professors exceed the supply, and they are interested in conserving faculty time. Another side should be stressed, viz. that of the students. There are from 10 to 20 times as many students as faculty. Because of the rapid rate of progress in engineering development, the demand on the students is ever increasing. Thus, it is essential to determine and apply efficient methods of instruction for their sake.

Research to determine efficient learning procedures is essential. It is as essential to engineering education as research is to large companies employing engineering where a large per cent of the engineering talent is devoted to research to determine better products, new products and more efficient methods of producing them.

At this time there should be a move to initiate more scientific research in the field of engineering education. Yet one must not oversell the idea of research in education. Not everyone should be doing research. If too many projects are in progress at the same time, there will be interacting effects which may be hard to isolate. One must, as is done in industry, distinguish between research and production. Industrial companies have found that about 5 per cent of their effort devoted to scientific research is healthy. Perhaps no more than this amount of research in engineering education would be desirable.

2. What is Research in Engineering Education

Unfortunately, although the engineering educator has recognized the importance of research in engineering education, and there are many reports of the effectiveness of different methods for teaching this or that subject, reports of how to evaluate a teacher in some field or other, and reports of the usefulness of this or that screening examination, a critical survey of this material discloses that much is surprisingly lacking in the most rudimentary aspects of scientific rigor both in problem statement and solution. Some of the more frequently occurring non-rigorous approaches are:

1) Arm Chair Philosophy: From wide experience (usually limited to his own), the writer proceeds to draw conclusions. While the benefits to be derived from learning through experiential history are not to be depreciated (since this learning obviously has its place in tempering future work), the fact remains that reports developed from this approach leave the reader with the necessity of differentiating as to where generalizations on the experience of the individual have ceased and research has established fact.

2) Out of Context: In a surprisingly large number of papers a problem in engineering education is resolved with no consideration of other existing forces in the system which may influence the result. For example, the effectiveness of two different methods for teaching hydraulics might be under study. It could well be that preceding teaching procedures through which the student acquired his knowledge of mathematics

could condition the effectiveness of the instructional methods for hydraulics. Studying the hydraulics teaching methods out of context of the hydraulics-mathematics instruction system might, therefore, lead to erroneous conclusions.

3) Biased Experiment Plan: The answer to a particular problem is evolved through deduction, and experimental procedures are then set up to verify the deduction. When an experiment is set up with a desired answer already in mind, there is considerable risk that the problem under study will in reality remain unsolved with the experiment yielding only the answer it was designed to yield.

4) Incomplete Plans: An instructor decides to report on some technique, but finds that although much of the data needed to demonstrate the effectiveness of the technique are available, some key control data are missing. He proceeds to report the technique anyhow, stating that conclusions are based on postulated behavior of the "missing link" information. More often, the report comes out in an even weaker form, that is, with conclusions drawn and nothing said about the gaps in the information.

Without debating the prevalence of such non-rigorous approaches in educational research in curricula other than engineering (or in other research areas for that matter), the paradox remains that professional engineering educators, who utilize the most rigorous experimental methods in studying problems related to engineering systems, and whose pedagogical objectives relate to transmitting these rigorous skills to their engineering students, appear somewhat lax in applying the same rigor to their evaluations of their own teaching methods. It would thus appear useful to review some of the salient points of the logic and methodology of rigorous experimentation along with their pertinence to problems of evaluating engineering educational methods.

Any experimental research complex can be regarded as a systematic arrangement of procedures which begin with the problem recognition and proceed to ultimate solution through a sequential system of: (1) problem survey, (2) experiment planning, (3) performance and analysis, and

(4) inductive inference. A schematization of the entire system has been developed and is shown in Fig. 1*. Let us briefly describe the major aspects of this system.

Problem Survey: The objective of the problem survey phase is to formulate the problem to be considered starting from some prior recognition of the problem area. Judgment of personal experience, background knowledge, and careful study of the related work of other investigators together lead to the final formulation of the problem.

Experiment Planning: The objective of the experiment planning phase is to arrive at the most efficient statistical and experimental methodologies for testing specific hypotheses bearing on the formulated problem. This phase includes: (a) the statement of the hypothesis for test, (b) the statistical plan for testing the hypothesis, and (c) the experimental methodology necessary to implement the statistical plan. Any of a number of hypotheses can be set up pertaining to the problem. The statistical plan implies knowledge of the involved population parameters, the nature of their distributions, methods for estimating them, randomization requirements and other factors contributing to the applicability of the probability model upon which the hypothesis test is to be based. Planning of experiment methodology refers to establishing the specific techniques for making measurements during actual conduct of the investigation or experiment.

Both statistical and experiment methods planning must proceed in parallel from the statement of the hypothesis. This is illustrated in Fig. 1 by the use of solid connecting lines. In the process of developing the statistical plan, new hypotheses for test may be developed which can be considered as feedback effects (shown by dotted lines) from the statistical modeling step back to the statement of hypothesis. Similarly, in planning the experimental methodology, new hypotheses for test and possibly even new statistical plans may become apparent. Thus, in this framework the statistical and experimental methodology, cannot be planned without prior knowledge of the hypothesis under test but can feed back information to each other as well as to the hypothesis formulation.

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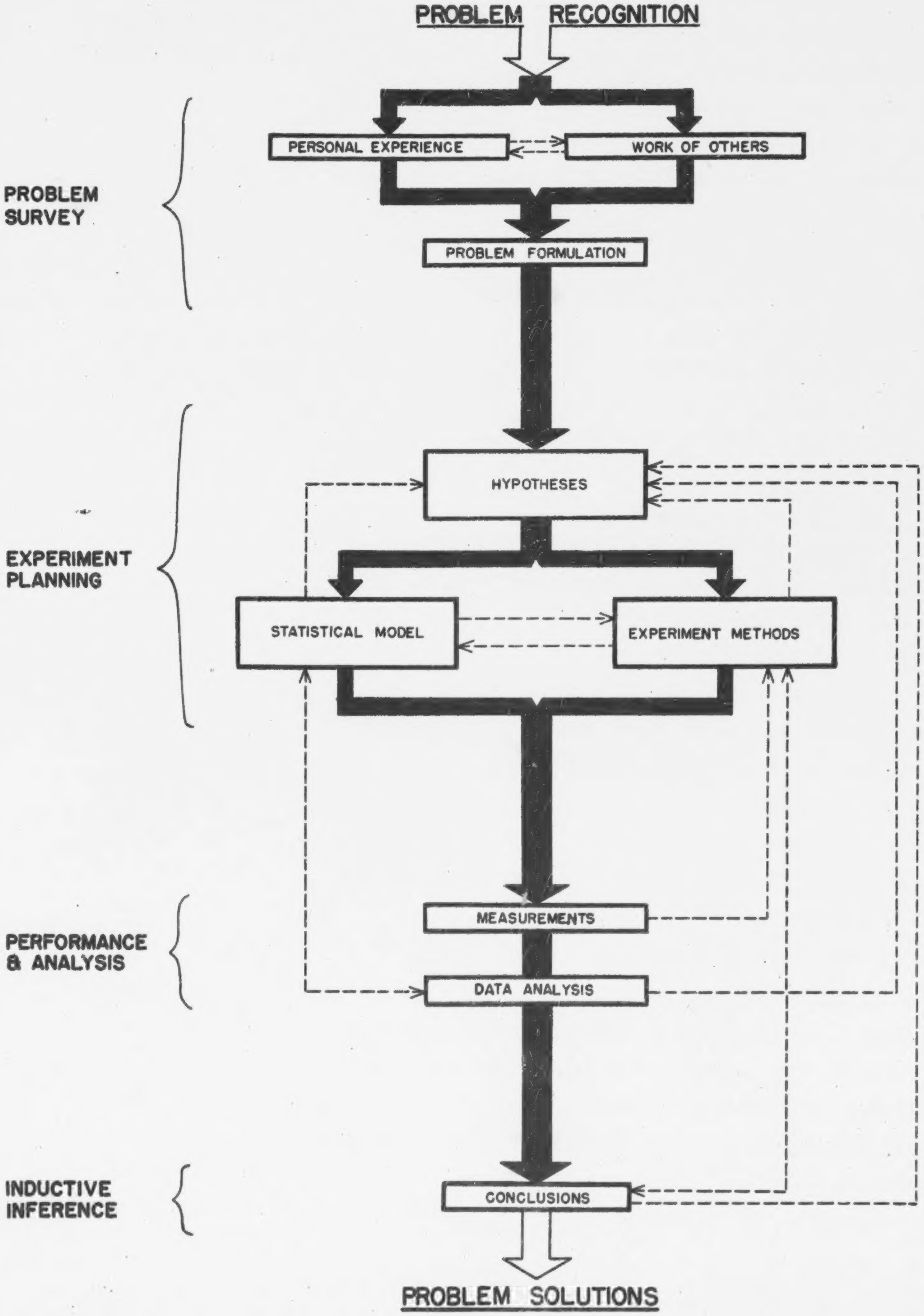
*The schematization of experimental research methodology is the joint effort of Dr. Heinz Haber, Dr. George E. Mount, Mr. Slade F. Hulbert, and the authors of the Department of Engineering, University of California, Los Angeles.

EXPERIMENTAL RESEARCH METHODOLOGY


PROBLEM RECOGNITION
PROBLEM SURVEY
PERSONAL EXPERIENCE
WORK OF OTHERS
PROBLEM FORMULATION
EXPERIMENT PLANNING
HYPOTHESES
STATISTICAL MODEL
EXPERIMENT METHODS
PERFORMANCE & ANALYSIS
MEASUREMENTS
DATA ANALYSIS
INDUCTIVE INFERENCE
CONCLUSIONS
PROBLEM SOLUTIONS

Performance and Analysis: The performance and analysis phase of the system includes the making of measurements and the analyzing of them. Techniques for doing both should already have been established at the planning phase. Thus the complete planning triangle (hypothesis to statistical plan to experiment methodology) is a mandatory prerequisite to the actual experimentation and data. Of course, as the experiment is conducted, new ideas for experimental methodology may develop which in turn would have to filter through the planning triangle, and similarly after data is analyzed different statistical plans or hypotheses might be suggested. Thus this latter phase can feed information back to the planning phase.

Inductive Inference: Inductive inference is the last phase of the system and deals with reaching conclusions on the hypothesis under test. The conclusions, in turn, can suggest solutions to the original problem or, in the feedback sense, can suggest new hypotheses pertaining to the problem.

The preceding discussion is necessarily an oversimplification of the process involved in the scientific method. But it serves to demonstrate how engineering educators depart from it and proceed to non-rigorous treatment of their pedagogical problems. In the main, such departures are associated with inadequate planning, either at the problem formulation or experiment planning level, and differ from each other primarily in the degree to which the planning phases are skipped. For example, in the Arm Chair Philosophy approach the reader is taken from the problem recognition directly to the inductive inference stage. The performance of the experiment and analysis of the data essentially is the distillation of long years of experience of the individual author and perhaps his associates. There usually is limited evidence of any clear problem formulation and no evidence of any aspects of the all important methods planning triangle. In the out of context papers, problem formulation is obscure, the feedback from experiment methodology to hypothesis statement is completely ignored, which also would be the case in the biased experiment papers. The incomplete plans spring up primarily because planning, if there was any at all, would have been done after the experiment was performed: that is, after the data had been collected.

Any engineer is quick to see the dangers of trying to report on a technical problem to a client on the basis of wide experience only with no supporting factual material; or to plan and proceed to an experiment without considering whether the experiment already was performed by another; or to try to make sense out of data which has been collected under loosely controlled conditions. In short, engineers are completely aware of the importance of careful planning in experimental investigations relating to mechanical, electrical, thermal, or chemical engineering systems. Engineering educators, similarly, must realize that controls and the most complete possible prior specification of the problems are just as necessary in investigations relating to learning processes. In fact, the vast complexity of measuring learning and their antecedent teaching processes probably makes prior planning here even more important than in engineering systems.

Large bodies of data for evaluating engineering materials can be readily collected including biographical information on students, their performance in previous course work, their teachers, books, etc. Without careful prior formulation of the problem to be considered, the pertinent hypothesis, and the statistical and experimental methodology, a report prepared from even bountiful measures of such data can be expected to be of limited value. If, on the other hand, there is careful prior planning, the investigator will have at least a reasonable chance of achieving solutions to his problem; and such work, of course, should be reported to the profession.

Before carrying out research, it may be necessary and desirable to have exploratory work, preliminary tests, develop methods and skills related to the new idea before the rigorous research design is made. These steps should not be considered research. In the first step for research, the formulation of the problem, there is room for search or qualitative work. In the engineering field one does not test and measure all configurations and all designs. Some judgment is always applied before the measurements and tests are elaborately conducted. This judgment may be based upon preliminary crude tests, may be based upon vicarious experiences, or may be based upon pure hunches. Nevertheless, by some procedure, a search should be made to determine important problems worthy of research.

Although the authors of this report have stressed and are mainly interested in rigorous, quantitative, experimental research, in the U. S. Department of Health, Education, and Welfare, Office of Education Bulletin on "Analysis of Research in the Teaching of Sciences" describes three types of research:

A. Experimental studies include comparisons of learning under different methods or conditions of teaching and all other investigations that involve pupils in one or more types of learning situations. They are characterized generally by the following steps or techniques:

1. A statement of a carefully and specifically defined and delimited problem.
2. A thorough study of the literature appertaining to the problem, for the purpose of determining the need for the study and its possible contribution.
3. The development and use of an appropriate experimental design.
4. The collection of data and their treatment by appropriate statistical techniques.
5. A presentation of the findings and of the conclusions that seem justified by them.

B. Analytical studies are systematic attempts to determine from published materials, cooperating teachers, field studies, and other sources such factors as the aims that govern or that should govern the teaching, subject-matter elements that are taught, the relative importance of topics, facilities needed for teaching, and the like. Analytical studies are characterized generally by the following steps or techniques:

1. A statement of a carefully and specifically defined and delimited problem.
2. A thorough study of the literature appertaining to the problem, for the purpose of determining the need for the study and its possible contribution.
3. A selection or invention of a technique appropriate to the problem and also one that provides means by which the validity and the reliability of analysis may be determined and maintained.
4. A presentation of the findings and of the conclusions that seem justified by them.

C. Synthetic studies are investigations in which various curricular materials, resource-use data, instructional suggestions, references, aids to teaching, and the like, are brought together into some unified pattern so as to be helpful in an educational situation. Synthetic studies are characterized generally by the following steps or techniques:

1. A statement of a carefully and clearly defined need or objective.
2. The development of criteria for maintaining selectivity in the use of materials and the consistent use of the criteria in thorough studies of materials appertaining to the need or objective.
3. The development of a practical pattern or technique for organizing the materials that met the criteria.
4. The preparation of a substantial publication that summarizes the results of the studies.

It is obvious that the foregoing types, or categories, of research are not mutually exclusive in all respects. Analysis often enters into studies that are primarily experimental. Certain types of synthesis may appropriately be a part of an analytical or a curricular study.

3. Detailed Steps for Research in Engineering Education

For an experiment in Engineering Education to be called educational research, the following steps should be taken:

1) Obtain precise statements of the specific objectives of engineering education.

In any endeavor one should know what he is attempting to do. Sometimes in education the objectives are fuzzy. However, in engineering education the American Society for Engineering Education has given this problem a lot of thought and has stated the objectives clearly.

2) Determine the specific objectives of the particular education process which are being performed in more than one way.

One of the basic problems in education is to clarify the role of each of our courses as a fundamental (or not) building block which leads to the fulfillment of the general objective. The specific objective to be obtained from the course or unit under study must be clear or otherwise there is no logical basis for interpretation of the deviations in results obtained. The objective for any course should in some special way help to fulfill the over-all objectives.

3) Develop Measures

Before one can judge the relative merits of a process, method, or procedure one must compare in a quantitative sense. In order to do this one must develop an ordering scale. More specifically, one must develop tests which measure the contribution the various achievements give toward the objectives. Without a measure one cannot conduct research.

Under the usual operating conditions it has not been a common practice to compare achievement of students of different instructors. In fact, often an instructor does not in a precise way compare the results of his own students in different sections because he must give different tests, and he cannot validate them. Perhaps a reason for the non-comparison of the achievement of students between instructors is the lack of competition. In industry it is said that competition is the life of trade. Surely it encourages people to produce better products. In the academic market place, research in the subject matter areas has been sold on a competitive basis but not the teaching effort, at least not on a national scale. And as a result, persons in the instructional area are not accustomed to having their product measured and carefully scrutinized. As a consequence, they have not thought enough about the development of tests and measurements which determine a good product in terms of the objectives of engineering education. One should not get the idea that standardized tests should be developed and remain fixed once and for all. Far from it. The objectives of engineering education and the associated knowledge are dynamic. They are not static but continually changing. So tests and measuring rods must be extendable. Yet one must realize that in order to carry out useful research in education, one must be able to measure differences. Measurements are the keys to science. It may not be known how at present, but every day more is learned in the engineering education area. This measurement angle cannot be overstressed, for much of the best educational research today is coming up with the result "no significant difference." There are differences, but the measures are not fine enough to isolate them. It goes without saying that the differences must be in terms of the objectives of the unit as an integral part of the overall objectives of engineering education. It should be stressed that the tests should cover all of the objectives of the course, not just a sub-set of them which are fulfilled by all treatments. The tests should encompass all of the materials related to all objectives, not just the sub-set of the materials covered in all sections. The question should test thinking ability, simulation and coordination of ideas, methods of attack in problems, as well as facts and precise solution of problems.

4). State the Problem - Prescribe Treatments

When one has an idea for another way of accomplishing a task, which he thinks is better than the one currently in operation, perhaps he should test it. However, before one starts to rigorously determine whether his idea is good or bad he should clearly state what is different in the procedure or procedures. One should spell out precisely what is to be done, how, and for how long. The plan should be made in complete detail before he starts the rigorous test. (Note the exploratory work may and should proceed this detailed plan.) One should be sure the procedure tests the hypothesis. It is so easy to vary so many things that one does not know what he is really testing. In some of the best work in this area the results have been confounded and the interpretation misled by using a procedure which does not test the hypothesis. For example, recently the Journal of Engineering Education had an article on an experiment to determine the importance of class size. The experiment really didn't determine the effect of class size for the method of instruction was decidely different in the large classes than from the small classes. Perhaps it was the new method which was superior to the old and the effect might have been the same regardless of the class size. Or it might have been superior for the small class size thereby reversing the published conclusions. For a complete experiment the effects could have been measured in two steps thereby avoiding the confounding.

A second important point is the experiment must be conducted for a long enough time for the treatment to produce results. A psychologist designed a clever and intriguing experiment. He had laid out in detail each treatment. He devised the test carefully. When he got his measurements, he was disappointed the expected differences did not appear. Upon a careful view of the experiment he should not have been surprised, for the different treatments were given only nine times in a course with 45 periods. It takes a lot of drops of water to wear away a hard stone. The treatment must be given long enough.

5) Arrange for a Control Section

In order to determine the effects of the change of a new procedure, methods, it is essential to have some sections which have the null treatment, that is, they would be taught as they have been in the past. The control sections should be given the same tests as sections with new treatments. When there are multiple sections at the same hours it is simple enough to arrange for the test and the control groups. When there are multiple sections but at different hours then a common time, perhaps in the evenings, should be arranged for the common tests. When there are not multiple sections during the same semester, one can make the assumption that the students being taught are a part of the universe of all students, past and future, so the control section may be one year and the test sections the other years. (The years for tests should be randomly selected.) Here the tests must be different but a relationship between them may be obtained by giving the two tests to alternate members of a later class. In any event the experiment must be limited to a few set types of instruction among which should be the procedure currently in vogue. This latter one will serve as a control.

6) Random Selection of Students

Statistical techniques which have proven to be such powerful tools in the analysis of results in quality control, agriculture, and other sciences are not applicable unless the students are randomly selected. Nature is full of variations. These variations may result from the treatment or by chance alone. The problem is to determine the probability that they resulted from the treatment.

Although the random selection of students has not generally been done, it can be done. At The Pennsylvania State University the sections of courses under experiment have been listed in the time table by groups (Group A, Group B, etc.). The groups of students for these sections are formed by employing a table of random numbers and a roster of all students who are to take the course in question. In order to make the scheme work precisely, it is necessary to work out the entire schedule for each of the students and, at registration time, to hold the line or the whole effect of the randomization would be lost. Last year in forming the groups for an experiment in physics, the students were first stratified by curriculum: Civil, Mechanical, Aeronautical, Agricultural, Industrial, Architectual, Electrical, and Chemical Engineering. Within each strata the students' names were drawn so that each had an equal chance of being in the various test and control sections. Some students have indicated they did not desire to participate in an experiment, but when it was explained to them the importance of research to engineering and it was stressed the importance of a good engineering being open-minded on research, they have willingly participated.

7) Control or Isolate as Many Variables as Possible

The last paragraph stated it was necessary to select the students at random. This would not be true if students were identical for then the student variability would be eliminated. There are other ways of eliminating or isolating the effect of variability in the design of the experiment.

If the number of faculty members involved in the experiment is large they, too, should be selected at random. Actually the number of faculty members involved is usually small, so small that it is best to design an experiment which eliminates the variance due to teachers. This can be done by a factorial statistical design where, in essence, all the instructors participate in the course loads, and other variables should be eliminated or controlled. Another type of experimental design which may be employed for this purpose is the Latin square.

The ideal experiment would be one in which even the student environment is controlled. There is always interaction between the students through their contact outside of the classes. It should be assumed that if the new technique is desirable, eventually there would be only this type of instruction. Ideally they should be separated. This could be done by assigning the students to dormitory areas by random numbers and then giving all students living in a dormitory area the same instructional treatment. Or perhaps better still various schools should cooperate in the conducting of important experiments.

The importance of a careful design cannot be overemphasized. It is more efficient to have a good design and run the experiment once than to have a poor one and to repeat it.

In order to reduce variances, perhaps more stratification of students should be made. Maybe the idea of matched pairs (or multiples) with random selection in each pair (or multiple) should be completely exploited.

8) Execute the Experiment Precisely

It doesn't matter how carefully an experiment is planned unless the plan is followed exactly from the start to the finish optimum results cannot be obtained. It takes patience and vigilance.

In experimentation in education, it's so easy to drop your guard and let exceptions to your plan enter. Students want to change sections. Instructors may decide before the evaluation time that the plan should be changed. They may want to give different examinations. They may conclude the new procedure is not desirable before there has been time for the treatment to take effect. Don't yield! Hold the line! Change only after a new and valuable plan is evolved. Remember, no plan worthy of testing should be so poor that it would yield permanent detrimental results to the students. In fact, the odds should be in favor of improved instruction for them before an experiment is undertaken.

Any new procedure will at first require additional effort on the part of the instructor (habits are hard to break.) Yet, for research this effort must be expended throughout time. It is not advocated that each minute of the hour be programmed, there must be some variability within the design, but the variations should be limited to those absolutely necessary or planned.

9) Measure in a Uniform Manner

In making physical measurements we correct for temperature, humidity, etc. The measurements connected with educational research should be made as carefully. The tests developed for measuring specific achievements of the course should be given at appropriate times under uniform conditions, environment and time. In grading the papers, a differentiating scale should be used, which has a total of several hundred points so as to avoid fractional units. The points to be assigned to each correct and/or incorrect response should be fixed before the grading operation is started. A random view of some papers might help in establishing the point scale. Remember the tests are to measure thinking ability, simulation and coordination of ideas, methods of procedure, interest in subject, factual data and problem solutions. Hence, points should be alloted to success in these various realms.

Usually it is desirable to grade one question at a time. Even then it has been demonstrated that graders' standards will vary up and down as they proceed through a large number of papers. If there are several graders, each grader should grade the same questions on all papers.

Ideally, the testing and grading for the research should be done by someone other than the instructor. The individual instructor should feel free to grade in any manner he desires for the course grade. This is necessary for several reasons. Utmost among them, it is necessary to obtain cooperation.

10) Analyze the Results

This is the all-important step. What does the data reveal? Perhaps the first question to ask is, "Is it logical to compare the results?" In engineering, before one puts a product on the market for the scrutiny of the purchaser, he first develops it. He makes a mock-up, then builds prototype models, then tests models and thoroughly studies the device until its potential usefulness is understood as well as that of its competitors. Then, and only then, is he willing to put it to the strenuous tests of comparisons. So in the education area, one must be careful to be sure one has done the preliminary development work before he submits the idea to a comparative test. For example, it isn't logical to compare the results of instruction on TV with that of face to face instruction in small classes if the instructor has had no previous experience on TV but has had 20 years of the usual type of instruction. Of course, the development and the pilot testing should have been done before the rigorous experiment is made, unless the added difficulties for making complete measurements as the development progresses are not excessive. If they are not excessive, much may be saved in time and experience. Yet caution must be injected in the interpretation of the results.

This does not mean that one should not carry out the pilot runs as rigorously as the "production research" runs. In fact it indicates the contrary the pilot tests should test all parts of the design. Moreover some information can be obtained from these pilot runs.

Once the experiment has been conducted in the "production research" pattern the results are ready for interpretation. Even though the students were selected at random, it is desirable to have a leveling factor (covariance variable) to adjust for individual differences of students. In terms of this variable (previous grade point average, I. Q., placement tests, etc.) one should run a covariance analysis to determine what are the probabilities of the results occuring when there was no difference in achievement attributable to the method of instruction. Such a procedure is explained in many statistical books.[1]

Frequently, the sample size may be small and for this and other reasons the results may not be significant by the type of analysis given above. When this is the case one should not destroy the information with the comment no significant difference. The probability of the differences existing by chance should be given. If several experiments of a somewhat similar nature are conducted maybe an isoparametric technique can be applied to give a meaningful result.

When making the analytical comparisons, due consideration must be given to the drop-outs. The number of students taking the final examination is nearly always less than the number enrolled. Many of these withdrawals, officially or otherwise, may be related to the method of instruction. It is almost axiomatic that the bulk of these withdrawals are students having scholastic difficulties; hence, other things being equal, a comparison based upon a statistical analysis of the examination grades only would be expected to make the classes with the smallest number of drop-outs appear to have the poorest instruction. In one of our experiments on the grouping of freshmen engineers at The Pennsylvania State University, it was found that five percent more of the boys withdrew from the control than the test groups. In making the comparison of the overall achievement, a correction must be made for the difference.

When there are apparently no essential differences in achieve ment based upon test results, a careful look should be taken to see if there are other pertinent factors which admit a numerical measure. In one of our experiments the time devoted to study is being estimated. Surely the method which yields the same achievement and retention in less hours of concentration is the best one.

11) Publish the Results

Regardless of what the results actually show, these facts should be clearly explained by a publication in a well known journal.

Far more about methods and procedures for instructing engineers may be already known than is practiced anywhere. Maybe one of the biggest problems is communication. Surely this is an area which should be expanded. So, if anyone obtains sound results from experimentation, the ideas should not die with him but should be published so others could benefit from his labors.

4. Problem for Research in Engineering Education

With the rigorous foundations for research in the foreground, it is logical to think about the problem which should be investigated.

The problems for research in engineering education may relate to methods of instruction, curriculum content, order of curriculum content, grouping of students, importance of laboratories, utilization of manpower (students and/or faculty.) In short the research may be on methods, materials, management and men. Thus, there are many areas for research.

One of the biggest problems in instruction is to insure that communication of an understandable form is taking place between the instructor and the students. In some manner the instructor should have built-in antennas which are tuned to the frequency of the thoughts of each of the students in his class. In a way, experienced teachers have always modified their procedure in accordance with the reaction of the class as determined by facial expressions and other reactions. This type of activity may be compared to that of a pilot flying without instruments. He hears the engine; he feels the wind; he observes the trees and earth and controls his aircraft according to feeling (flying by the seat of his pants.) Aviation has progressed a long way from this type of flying. There are instruments that measure and indicate the motion of the airplanes. There are even mechanisms (autopilots) which automatically make adjustments without requiring the action of the pilot. Are there instruments which should be employed in the classroom that would permit us to change from flying by the seat of our pants to all-weather flying? What is the instructional equivalent to an auto-pilot? At the elementary school level learning machines are being built. What device can the engineers produce which will enhance learning at the college level? The development of better methods of communication is the first big problem for research. Communication which will admit corrections for individual differences.

This is a most general problem. Recently, Carpenter, in a paper defined the functions of the teachers and those of the student. In between these two he listed the qualities of the communication system. It is in this connecting system that only the surface has been scratched.

5. Current Investigations in Engineering Education

During the year 1959 a survey was made of those individuals who were actively investigating problems in Engineering Education. One hundred sixty investigations were reported. Of the one hundred sixty investigations, by far the greatest number of studies were related to the problem of student selection--fifty two were reported. Twenty of these were research attempts in which the experimental design had been carefully worked out and adequate controls were being used as a check on the results. Nineteen of the fifty two had arrived at conclusions although some of these were tentative. Eleven studies had been completed. The very nature of these investigations encouraged a long continuing type of study, since the follow-up of students through a college takes at least four years. The scope of the work was interesting since it reflected the problems confronting the colleges or those that might be expected in the future. It extended from an analysis of the student's background and its relationship to his subsequent success or failure in college through the use of standardized tests such as the College Entrance Board Examination (and in some instances specially designed ones created to meet a unique situation or the needs of a particular university) to tests and other methods of exploring the effects of interest and personality on the student's subsequent academic career. Even those intangibles called creativity and motivation were being looked at thoughtfully to see if they could be quantified and utilized as part of the appraisal process.

In general, within the next few years we should have an abundance of information which should allow us to select indices that will assure the entrance of students who have the ability to achieve at a higher level of teaching than has been the case in the past. Years from now we probably will be grateful to those whose hard work prepared the way for the on rush of students and avoided the elimination of prospective students by rule of thumb techniques. Here, incidentally, is an area in which it is fairly simple to develop a good research design; the tragedy lies in the fact that in many instances a vast amount of work is being devoted to an analysis that is faulty either because of the lack of suitable criteria or the failure to use a control group. Perhaps, if you think that we are over-emphasizing the importance of careful work in this area, you might keep in mind that faulty techniques in our selection process could easily result in the best students being kept out of college while the mediocre ones were allowed to enter.

The next area of greatest activity in engineering education appears to lie in the problem of what should be taught in a course. Eighteen projects were active in this field and, as might be suspected, almost all of them consisted of individual instructors or committees analyzing course content and then rebuilding it to eliminate what was believed to be the previous defects. And because the problem of what constitutes suitable criteria becomes of great importance in these activities, the majority of the investigations were not of the type that could be called controlled experimentation. A common method of appraisal of the success of the experiment was to base the conclusions upon personal observation of the instructor (who was usually also the experimenter) or upon the results of a survey of the members of the class participating in the experiment. Since it is possible to establish experimental controls (although it does involve considerable work and careful planning,) it is unfortunate that more carefully planned experiments are not apparent in this field of endeavor. This is particularly true when you consider that instead of the report eighteen, there must be hundreds of individuals who are actively tampering with course content. Interestingly enough and tying in with the increasing emphasis on selection, many of these experiments seemed to be aimed at revising the course material in such a way as to tighten up the learning experience. Sometimes this was done through improving the subject matter and sometimes through the use of tutorial and/or other facilitating experiences to give the beginning student a sound basis upon which to build his later academic career.

Eleven studies dealt with the problem of what to do with the individual who was once almost unheard of - - the superior student. These covered among other things the development of flexible programs, special honors courses, allowing undergraduates to take graduate courses for latent credit and carefully controlled studies to probe the superior student who under achieved. Of the eleven studies only two seemed able to carry the title of systematic and controlled research; the others were basically surveys or descriptions of how a committee or administrator had resolved the problem. Probably what is really significant is that interest in the superior student has reached the stage where some definite exploration is under way. It is highly conceivable that many other schools are also working upon the problem, but simply consider it as an administrative matter and do not trouble to mention it. It seems possible at this time that as the groups of gifted students become known and marked more and more research will evolve which will focus on them and their activities.

Television as a teaching medium has come under considerable scrutiny. Since it involves the possibility of extending the individual to numerous groups, it has received much publicity; and, as a result, some of the investigations have been more spectacular than scientific. Eleven individuals reported that they had been active in this field. The studies varied from very carefully planned research designs to the introduction of a course for non-university populations without any follow-up to determine the results. Perhaps because it exists in most of our homes, many of us have thought of its possibilities as a teaching medium. It is interesting to note that in one research into its potential usefulness no significant differences were found between the students being taught through closed circuit television and students taught in the regular manner. It would appear that to fill the gaps in our knowledge concerning television and other media closely related to it we need a series of carefully planned and coordinated research activities with less of the one shot and no follow-up type of activity.

Class size has come in for some exploration. Perhaps the pressure of how to avoid endless numbers of classes has made this area the subject of more carefully controlled investigations. At any rate, five out of the ten studies reported could be tabbed as being well designed experiments. The experiments undertaken showed variety, ranging all the way from straight lectures for large classes to the use of a single lecture with auxiliary small discussion groups. Some investigation has been undertaken to explore the possibility of using special devices (projectors, etc.) which would enable the instructor to make better utilization of his time and give a more effective presentation.
The subject of drop-outs seemed to be a fairly interesting one to a small group--mainly consisting of assistant deans, registrars, etc. Their search into the reasons for termination included such variations as an investigation to determine the factors affecting drop-outs with respect to junior college transfers, some simple statistical studies, a tabulation of the reasons causing freshman drop-outs, and a more exhaustive analysis of the drop-outs to see what had happened to them. Again, while these investigations could not be called true experiments, they will contribute knowledge to the teaching of engineering.

Even methods of teaching have come under some scrutiny. Of six reported, four appear to have been carefully planned research which eventually should throw some light on the method of teaching. Investigations have included experimentation to determine the relative merit of lecture vs. recitation, the relative effectiveness of the discussion method with small groups, and an analysis of the relative value of individual activity vs. group participation. Undoubtedly, here lies an area in which a great amount of carefully controlled research could prove to be of immense profit to the profession.

Curriculum development has come in for some examination. The investigations primarily center around the concept of developing a basic core to underlie the curriculum. This core ranges in various institutions from a limited number of required units to a total, unified sequence with no specialization. In one instance a non-fixed curriculum is being used with considerable latitude existing for the advisor and the student in the development of his individual program. Because of the increasing emphasis on the science of engineering it is to be expected that additional explorations of the structure of the curriculum will appear in the future. These experiments and the results which in some instances are becoming apparent may be expected to produce ultimately changes in the concept of engineering education.

Six studies were reported in this area. While they were not established in the strict sense of an experimental research project, they, nevertheless, range considerably in the controls and follow-up that is being made of them. Five studies were concerned with the problem of developing the future crop of engineering teachers. The reports made by those active in the field ranged all the way from an actual internship to the conduct of informal seminars for seniors and graduates who planned to go into the teaching profession. As might be expected, most of these studies could not be classified as research but rather as an attempt on the part of interested individuals to do something to offset the very obvious shortage of teachers. This field is one in which some carefully planned studies could be of considerable advantage in shortening the length of time it takes a young man entering the teaching field to become proficient and in influencing promising students to take an active interest in the teaching profession.

The graduate student has come under some scrutiny as a result of five studies. Most of the studies pertaining to graduate students consisted of a follow-up survey to determine the fields he had entered, courses he had taken, what he felt was most useful, and similar information of interest to the colleges. Two of the follow-up studies of graduate students appear to be very carefully developed surveys. In addition to the graduate student the freshman has also come under considerable scrutiny, four investigations being reported two of which were experimentally controlled. The areas of investigation extended from examining the problem of marginal freshmen to determining the merits of a tutelage program for the beginner in college. Three studies each were reported relating to the use of films and teaching machines. One of the film studies is being reported at this meeting and is a well thought-out and carefully controlled piece of research. The other two were reviews of the use of slides, films, and tape in the teaching situation. Three studies dealt with the sociological background of engineering students and were primarily concerned with the student as a sociological entity. Even the problem of reading difficulties turned up as suitable material for experimentation in two studies. The prior history of the entering student forms the subject of two other studies. In addition there were a number of other studies that did not seem to fall under any general classification. These ranged all over the field and included an investigation of individual study habits, an analysis of the attitudes of postgraduates after they were employed in industry, and the development of a study guide as an aid in the quick comprehension of the lecture material. Even the problem of construction of tests for the class came in for some study. One respondent to our letter of inquiry indicated he had been engaged in the development of completion tests for use in certain courses.

Another experiment investigated the possibility of grouping students by motivation. A comprehensive study has been completed on the roll of cooperative education. An interesting and somewhat different study appears in which an attempt was made to analyze the student's difficulties in terms of the interaction of his goals and the faculty's goals. Other studies included the development of screening tests for graduate students, the effect of high school courses on college work, and a study of factors relating to admission and persistence in college.

6. Examples of Research in Engineering Education

1) Relative Merits of a Lecture and Recitation Period in the Teaching of College Physics. Lancaster and others, Penn State

It was felt by some members of the Physics Department that the amount of material presented could be increased by increasing the number of lectures and reducing the number of recitations. In this manner the curriculum could be enriched. Not all members of the Physics Department shared these views on the advantages of more lectures, and over 80 per cent of the students expressed a preference for more recitations and fewer lectures. In order to answer this question the course was given three ways,

3R	1L	1P
2R	2L	1P
1R	3L	1P

where R denotes a recitation, L denotes a lecture and P a laboratory period. The students were randomly selected by curriculum. The tests were developed and graded uniformly. The achievement of the students increased significantly as the number of recitations increased and the number of lectures decreased.

2) Use of MARI. Lancaster and others, Penn State, 1959-1960.

MARI is a classroom communicator named from the words Motivator and Response Indicator. It is a two-way communicator. At the student's desk there is a counter and two buttons. On the teacher's desk there is a counter, a deal which reads in percent of the class and two buttons on a remote control cord. When a statement is made the professor indicates agreement or disagreement by pushing one of the buttons. Each student responds by pushing a button. If a student concurs with the teacher his counter moves up one. If he does not concur the circuit locks and nothing happens. The dial on the teacher's desk indicates the percentage of the students concurring with the teacher.

This device is based upon the idea advanced by the psychologists that an immediate response of a student to a correct answer is desirable.

Two classes in a course on Aircraft Stability in Control were taught by the same instructor, one using MARI, the other without it. The class using MARI showed superior performance.

3) Pilot Study: to construct program for teaching machine which covered one lecture and to test this program on 12 students enrolled in course. D. J. Mayhew, A. F. Johnson..... University of Utah.....January, 1959

Six students received program before lecture and six received it after lecture. Program was administered by human monitor, not by machine. Program required 3 hours for administration while regular lecture covered same content. A benefit from the instructor's standpoint was the increased understanding of the method of teaching a course that comes from making a program. The students who took the program were asked to answer two questions:

"...do you think this approach superior to learning from a text?"
7 students - Yes 3 students - No 2 students - Yes & No

can this be improved to replace, in part, classroom lecture?
11 students - Yes 1 student - No 0 students - Yes & No

Construction of trial program to replace one lecture required about 60 hours---40 hours were needed to reproduce and test it. Investigators felt all above could be reduced to 50 hours with more experience.

All above is qualified by the fact that the program was administered by human monitors and not by machine.

4) To determine the extent to which tests of the freshman battery could be used in the prediction of scholastic achievement in the Georgia Institute of Technology. E. H. Loveland and J. M. Richards.... Georgia Institute of Technology....1954

Of sixteen tests given to entrants in the Fall of '51, three tests were selected by statistical methods as the best predictors of scholastic success: the Georgia Tech Mathematics Placement Test, the Georgia Tech English Placement Test, and the Pre-Engineering Ability Test. These three tests could predict as well as a combination of all sixteen tests.

Weighted test scores were computed for each student. These scores were then transformed into stanine scores. First quarter grade-point averages were similarly transformed into stanine scores. For 673 entering freshmen who were not required to take remedial English or mathematics courses the precentage of freshmen in each test stanine who obtained average or above average first-quarter grades (a grade-point average stanine of 5 or higher) was obtained.

TEST STANINE	% OF FRESHMEN WHO ACHIEVED AVERAGE OR ABOVE AVERAGE FIRST QUARTER GRADES
9	100%
8	95%
7	93%
6	65%
5	54%
4	39%
3	23%
2	0%

(similar results were achieved on 1954 entrants who were treated the same way)

The test score weights were termed stable when the correlation between weighted test scores and grade-point average obtained on the '51 entrants did not differ significantly from a similar correlation obtained on '54 entrants (the correlations with first-quarter grades were .62 and .62 respectively and the correlations with first three quarters' grades were .62 and .64 respectively.)

In the '54 group students who were required to take the remedial courses in English and mathematics were treated. Only 41% of those who were required to take the remedial mathematics course, 38% of those required to take the remedial English course, and 35% of those required to take both remedial courses achieved average or above average first-quarter grades. 13.3% of those who took remedial mathematics, 8.0% of those who took remedial English, and 25.4% of those who took both remedial courses failed to complete three quarters in day school prior to winter, 1956. Only 6.8% of "non-remedial" students failed to complete these three quarters.

Continued study of the '54 entrants, through their remaining years, is in progress.

5) Research: to present data regarding the validity, reliability and difficulty of the Georgia Tech Mathematics and English Placement Tests.

Previous validity studies have shown tests to be good predictors of scholastic achievement (as measured by grade-point average) at Georgia Tech.

Reliability coefficients of .90 for the math test and .86 for the English test were obtained.

When an item analysis was performed, the tests showed a range of item difficulties, with a median difficulty of 56 for the math test and a median difficulty of 61 for the English test.

The majority of items on both tests were seen to be significantly related to total test scores. All the items of the math test except four were significant predictors of grade-point average. On the English test, however, one-fifth of the items were seen to make no significant discrimination between students who attained high grade-point average and students who attained low grade-point average.

6) Experiment designed to determine the relative effectiveness of two different teaching techniques as applied to courses in Mechanics of Materials I (CE 110) and Engineering Fluid Mechanics (CE 120.) John R. White.....City College, New York.....1957

DESIGN:

I. Course CE 110:

A. Two Groups: experimental (approx. 100 students) and control (approx. 180 students).....students were not forced into one or the other of the groups, rather, normal registration procedures allowed for the division

B. Experimental Group: 5 sections of 20 students each which met twice a week for common 1 hour mass lecture (32 hour semester total with no individualized attention) always with the same professor......and twice a week in separate sections for 1 hour of lecture-recitation (32 hour semester total with individual attention) with a different instructor.

C. Control Group: 9 sections of approx. 20 students each which met separately for 1 hour lecture-recitation 4 times a week. Reading and problem assignments were similar to the experimental group's.

II. Course CE 120:

A. Two Groups: experimental (approx. 80 students) and control (approx. 140 students).....same selection procedure as above.

B. Experimental Group: 4 sections of approx. 20 students each which met in common 1 hour lecture 60% of semester time (29 hour semester total with no individual attention) always with the same professor.....the remaining 40% of allowable time was spent in separate sections for a 1 hour lecture-recitation with a different instructor (19 hour semester total with individual attention.)

C. Control Group: 7 sections of approx. 20 students each which met 3 times a week for 1 hour lecture-recitation. Reading and problem assignments similar to experimental group's.

III. Graduates, non-matriculated students, and special students were omitted from study.

IV. In both courses the two groups did not differ significantly in terms of ACE scores, High School Average, Composite Scores (compiled by adding high school average and CCNY entrance exam average in science, comprehension, science vocabulary, and engineering math,) and City College Average (based on Chemistry, Drafting, Mathematics and Physics.)

V. Results: Comparing mid-term and final examination scores for the two groups in CE 110 indicated that the experimental group was significantly superior to the control group (standard errors not reported.) Comparing final examination scores only for the two groups in CE 120 indicated no significant superiority for either group---yet a trend favors the experimental group (no standard errors reported.)

VI. Results of Student Questionnaire for Course CE 110:

A. No significant difference in total hours spent by each group on theoretical material.

B. No significant difference in total hours spent on homework problems between the groups.

C. The chief advantages of the experimental method as far as student reaction was concerned appeared to be: (1) an experienced lecturer to conduct the mass lecturers, (2) a uniform coverage of material during the term, and (3) a rigid adherence to the course outline.

D. The main advantage of the Control Method appeared to be: (1) a closer contact between student and teacher and (2) a better opportunity to ask questions.

E. The chief disadvantages of the experimental technique from the student's standpoint seemed to be: (1) the tendency for lectures to become tiresome when given to a large group of students, (2) too close adherence to material presented in the textbook, and (3) the lack of opportunity to ask questions in a mass lecture.

F. Approximately one half of the students in the lecture-recitation group listed no major disadvantage in this method of instruction.

G. The control method was highly effective in developing the students comprehension of both subject matter and homework problems. The Experimental method was also highly effective in assisting students in the solution of homework problems but not as efficient in their understanding of the major topics covered in the lecture sessions during the course.

VII. Results of Students Questionnaire for Course CE 120:

A. The experiment group appeared (?) to spend more hours per week studying theoretical material.

B. The experiment group spent more hours on the solution of homework problems than did the control sections.

C. The chief advantages of the experimental method as far as student reaction was concerned appeared to be similar to those stated in CE 110 course.

D. The chief advantage of the control method was the same as that expressed by the CE 110 students.

E. The chief disadvantages of the experimental techniques can be summarized as the lack of the usual direct contact between student and teacher.

F. Approx. one third of the students in the control sections listed no chief disadvantage attributed to this method of instruction.

G. The control group was better able to comprehend the subject matter covered in the various topics discussed but appeared to have more difficulty in attempting to solve the homework problems.

7) The use of a prepared study-guide as a teaching tool. Gene B. Stock.....University of Arizona.....1958

The study-guide was initially developed in an effort to pass to the student the initiative and responsibility for adequate completion of course work.

The following are statements by the author concerning the development of the study:

"In the Spring Term of 1958 I was assigned to teach our EE 50 - - a course titled The Physical Basis for Electrical Engineering ..... The failure rate over the several years the course had been given averaged in excess of thirty per cent....The several men teaching the course all followed the conventional method, which I would classify broadly as the Lecture Method....I made every effort to stimulate class discussion and to arouse class interest....homework problems, collected and graded, were handed in on time by almost all of the students.... however, hour-exam grades were abysmally low, indicating serious failure on the part of far too many of the students to grasp the basic course material.

"I became increasingly convinced that the extreme passivity of the average student, his waiting to be taught outlook, was the main source of the difficulty.

".....at approximately mid-term I made a drastic change in my teaching method. I devoted one class period to a discussion of the problem.....I then outlined briefly the material to be covered in the text for a period of two weeks; assigned problems, stating that they would not be handed in by the student, and set an examination. I stated that there would be no lecture - - no consecutive presentation of text material, that class time would be devoted to elaboration and explanation of that material which the students brought forward for class consideration. I emphasized that the initiative rested entirely with the students.

"The examination grades following this experimental two week period showed marked improvement over those previous, although the class average was not deemed completely satisfactory.....Certainly there were a number of factors to be considered: was the material covered less difficult than that studied previously? Did the novelty of the method arouse the student's interest to the extent that he focused more effort on the course? Was the examination easier than those previously given? These were a few of the unknowns that made evaluation difficult."

(special attention should be made to these points since they are of major importance and some sort of control should be had over them.)

"In an effort to refine the method further, a Study-Guide of twenty-four questions was prepared covering the next chapter to be studied. These were passed out to the students. The guide paralleled the text development, the questions being carefully planned and worded with several objectives in view.....In general, it was felt that the physical act of writing or drawing served to focus the student's attention and that the organization and formulation of ideas necessarily preceding such activity would further the processes of understanding and learning. The class was told that the Chapter Write-Ups would be due at the time of examination; that it would be graded and would count as one-half the examination grade.

"Over the following three-week period, class time was used, entirely at the initiative of the students, in discussion, analysis, and elaboration....with the Chapter Write-Ups as a focus. Class participation was excellent....The completed examination was submitted for comment to two colleagues teaching other sections of the course. Both thought the test was very adequate--but, perhaps, a little too long. The examination was given and the class average was very high, approximately 80%, much higher than for any previous examination. Also the Chapter Write-Ups were surprisingly well done.

"A study-guide was prepared for the remaining sections of the text and distributed to the class. The same classroom technique was used as previously. Again the examination grades and the calibre of the Write-Ups handed in was very high."

Making use of the Chapter Write-Ups in Summer Session, 1958, Professor J. L. Knickerbocker reported, "....the students as 'very enthusiastic' about the study-guide method...Of fifty-three students enrolled for the course, there were only three failures."

In the Fall Term of 1958 the study guide was employed in seven sections of EE 50. Each instructor, however, used his own method of classroom instruction. For the seven sections, the semester failure rate was less than 10%. 72% of the students endorsed the method. During the same semester the author prepared a study-guide for EE 222 (AC circuit analysis.) The level of class achievement was appreciably higher than the previous class the author had taught covering the same material. In the class of thirty-one students, twenty-seven endorsed the method.

The author concludes, "In summary, it would seem that the study-guide was instrumental in raising the level of student achievement in the classes in which the method was used. A very substantial majority of the students in those classes reported that the method was of assistance to them in mastering the course material....the study-guide seemed equally useful when used in conjunction with formal lecture."

A word of warning is quite appropriate here and is presented in the authors own words, "I regret that I have no statistical tabulations to offer you--no objective data from which valid conclusions regarding the value of the study-guide method can justifiably be drawn."

8) Research: If the Kuder Preference Record Occupational Form D is to be used in the counseling of engineering students at Duke University it becomes necessary to ask whether civil engineering (CE), electrical engineering (EE), and mechanical engineering (ME) students significantly differ from each other in their expression of interests as measured by their respective occupational scales? Gehman, W. S., Kraybill, E. K., Katzenmeyer, W. G. Application of New Kuder Engineering Scales for Counseling University Students, J. Eng. Educ., Vol. 50, No. 2, Nov., 1959, 166-169.

Method: The subjects were 103 CE students (50 freshmen and 53 seniors),
131 EE students (65 freshmen and 66 seniors), and,
191 ME students (92 freshmen and 99 seniors.)

All were enrolled in the College of Engineering at Duke University during the years 1954-1957. Since past, unpublished research by Gehman showed that freshmen and seniors did not differ significantly in mean scale scores the freshmen and seniors within each interest group were combined.

Also, each freshman was asked to designate his major field preference as CE, EE or ME....if he was unsure then he was omitted from the study.

Answer sheets for the 425 students were scored for each of the three engineering scales.

A simple randomized analysis of variance was employed to determine the discriminative power of the three scales. (the means and SDs of

Kuder's "men in general" group were used as the best estimates of the population values for purposes of the conversion to standard scores.)

Results:

1. Each of the three scales differentiated all of the student groups from Kuder's "men in general" ($P < .01$)
2. The EE scale shows the greatest departure from the "men in general" for all three student groups. The authors conclude, "It might be inferred from this that the EE scale is the most efficient of the three Engineering Occupational Scales."
3. Regardless of the scale the EE student group scored the highest thus indicating that, "......the use of the scales for the purpose of selecting a specific area of specialization (CE, EE, or ME) within the field of engineering would not be supported by the results of this study." (this last conclusion must be received with some caution since, the EE group did not score significantly higher than the CE group on the CE scale, did not score significantly higher than the EE group on the EE scale, and did not score significantly higher than the ME group on the ME scale.)
4. By running correlations between the scores earned by the student groups on the scales investigated it was found that such correlations were significant and ranged from .60 to .93 ($P < .01$).....thus the authors conclude, ".....the scales are to a considerable extent measuring similar and/or overlapping factors."

The authors in general conclude, "The results of the present study do not indicate that the addition of the CE and ME scales to the Kuder Preference Record Occupational Form D has improved its usefulness in the counseling situation."

One added word of caution, the analysis of variance in this study was comprised of eighteen comparisons.....even with a significant over-all F (which incidentally was not reported) the probability values noted may be seriously midleading...not only could the true probability values be much more than those stated but also the trends noticed in some of the comparisons which were not significant could be completely reversed from their true nature.

9) Research: Out of a new theory of personality structure developed by Bills and Vance (1951) two hypotheses were derived; (1) "For a mature student population, prior scholastic achievement is of little value in predicting further academic

achievement and (2) granting to the prospective student an essential minimum degree of intelligence, the minimum prerequisite course credit, and the learning situation normally provided, an index of his values constitutes a valid indicator of the success that he may be expected to achieve in an educational program and on the job after training. Vance, Edgar L...... Air Force Institute of Technology....June, 1958 (progress Report No. 1)

The above general hypotheses, the authors claim, lead to the following specific hypotheses: Overall quality point average in AFIT programs cannot be predicted from the factors listed under column I below:

	I	II	
		"r"	"p"
1.	the prior overall quality point average	.295	.01
2.	the prior mathematics quality point average	.307	.01
3.	the combined prior physical science and engineering quality point average	.270	.01
4.	the combined prior mathematics, physical science, and engineering quality point average	.324	.01
5.	the prior overall quality point achievement	-.042	n.s.
6.	the prior mathematics quality point achievement	.223	.01
7.	the combined prior physical science and engineering quality point achievement	.105	n.s.
8.	the combined prior mathematics, physical science and engineering quality point achievement	.123	.05
9.	the prior total semester hours credit	-.002	n.s.
10.	the prior mathematics semester hours credit	.036	n.s.
11.	the combined prior physical science and engineering semester hours credit.	.009	n.s.
12.	the combined prior mathematics, physical science and engineering semester hours credit	.014	n.s.

and more specifically

13.	there is a negative relationship between length of time out of school and AFIT overall quality point average	-.107	.05
14.	there is a negative relationship between age and AFIT overall quality point average	-.125	.01

Pearson product-moment coefficients of correlation ("r") were calculated from data collected from approximately one-half of all graduates of the two-year undergraduate engineering program that leads to the Degree of Bachelor of Science in Engineering. These students are from 1948 through 1956 classes and come from a wide variety of colleges and universities located in all parts of the country. The correlations are presented in column II above along with their significance (p- values.)

The quality point averages were computed from credits which carried specific grades only. Not included were credits for which only a grade of "passing" or "failing" was given. These averages were computed by assigning 4 quality points to an "A" grade, 3 to a "B", 2 to a "C", and zero to a "D" or "F". Total quality points were had by multiplying the hours credit earned by the quality points assigned to the grade received and the sums totaled. These totals were then divided by the total hours credit attempted.

The authors conclude, in part, "Though the relationships found between the prior quality point averages, the prior math quality point achievement, age and time out of school and the AFIT overall quality point average are real, the tendency of the quality of AFIT work to vary with these background factors is so slight that we must accept the specific hypotheses drawn as regards the two-year undergraduate engineering degree group. Prediction of the AFIT quality point average from the above background variables involves such a high degree of error as to render them virtually worthless for the purpose.

The authors also go on to point out that a consideration of the schools from which the students came may be important. Such a study is under way but to this date no trend is evident which would indicate that a consideration of the school from which a student has come is critical to a prediction about his future success at AFIT.

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LEARNING TO FACILITATE LEARNING

Harold A. Foecke
University of Notre Dame

I. Introduction

The summary session of this institute has two major objectives: (1) to provide an opportunity to achieve some synthesis of the experiences of these past two weeks and (2) to consider the impact of of these experiences in terms of our activities on our respective campuses. The summary session will be most fruitful if you and the other participants bring to it the products of your own reflections upon the Institute. Consequently, it is the function of this paper to suggest the general outlines of a summary. You may use this outline as a framework for your own synthesis or you may reject it - - in which case I hope you will feel challenged to produce a unique summary of your own. In the language of this Institute, we want the summary session to be a profitable learning experience for you and this paper represents a set of stimuli which hopefully will establish an appropriate mental set for our final meeting and trigger your mind to discover meanings and relationships which until now have not emerged for you.

Were I to attempt to summarize every session or to try to condense each of the more than two dozen papers to some arbitrary fraction of its original length the result would be an indigestible mass of material. Fortunately, I have been told that my function is not simply that of an agile librarian scrupulously cataloguing all ideas irrespective of their relative importance. Rather, I've been asked to filter, mix, and integr ate the oral and written material which we have received during these two weeks. In the hope of keeping it mercifully short in the written material that follows I shall include only a portion of this active synthesis of our experience reserving for our final assembly other material which in my judgment we can consider more effectively in such a setting.

II. The Central Focus of Education - - The Human Learner

The brochure which announced this Institute identified it as an "Institute on Effective Teaching." Perhaps the thing which more than anything else symbolizes the spirit and success of these meetings is the dramatic and spontaneous shift of emphasis which took place before the end of the first week. Typical of the evidence of this reorientation of viewpoint was the slide which Dean Lagerstrom made during the audio-visual workshop. Against a suitable background were emblazoned the words "Emphasis on Learning." About this same time our Director, Dr. Lancaster, chose a slogan for the conference: "Achieve Learning Objectives."

Gagné had pointed out to us that the "central part of education as a system must remain . . . . the human learner." Tyler reinforced this by pointing out that the whole purpose of the teaching enterprise is to "facilitate desired learning on the part of the student." Preoccupation with the teacher and the activity of teaching, therefore, gave way to a concern for the learner and the activity of learning. I have therefore chosen the title of this written summary so as to reflect what I feel to be the genuine mood of both our scheduled meetings and our midnight kitchen bull sessions - - a desire on our part to learn how to facilitate desired forms of learning in our students.

And so our gaze turned upon Harvey Heckler, a unique product of this Institute, who symbolized for most of us some composite of the engineering students of our own experience. To help him and his classmates learn it became clear that we needed to refine our notions of learning, to identify the sorts of things which engineering students are expected to learn, and to acquire some insight into how learning takes place.

We saw that learning is defined in general in terms of changes in human behavior. Thus Gagné stated that "the neural process which underlies the occurrence of a change in performance, when not a result of growth or fatigue, is what we call learning." Tyler's implied definition of learning was essentially the same when, in a different context, he stated that "education is used to name a process that is concerned with changing the behavior of students - - using behavior to include thinking, feeling, and acting."

In reviewing the types of learning expected of students we found these characterized in somewhat different ways by different authors. Tyler referred to ideas, knowledge, skills, attitudes, and interests, whereas Gagné discussed discrimination, identification, motor sequences, verbal sequences, concepts, and concept sequences. But these differences (partly a matter of viewpoint and definition) were secondary in importance to our growing awareness of how fundamentally different are some of the things which students are asked to learn within the framework of an engineering education - - principles, concepts, skills, attitudes, facts, etc.

Regarding the conditions for effective learning. Gagné listed four (Motivation, practice, reinforcement, and freedom from distraction) whereas Tyler mentioned nine (not enumerated here). The differences between these lists were more apparent than real but again a precise list was not really as important as the realization (pointed out by Gagné) that while it is true that there are some general conditions for effective learning "it is of the utmost importance to recognize that different kinds of things to be learned take different kinds of learning conditions."

We saw that the concern of the psychologist is to infer the nature of the "behavior system" of the human organism on the basis of observations of the ways in which the organism transforms inputs (stimuli) into outputs (responses). What makes the task so difficult is precisely the fact that the organism learns, i. e., its "transfer function" changes as a result of interaction with the environment. Gagné cautioned that "while much is known about learning it would be useless to contend that the field of the psychology of learning is a highly developed and organized body of knowledge." Rather, he stated that "psychologists are still trying to define some of the variables."

Because there are a variety of theories to explain human learning we did not delve into all of these or even explore any one very thorouthly. Rather we concentrated on a better acquaintance with some of the basic phenomena which learning theorists attempt to explain. The requirements of brevity do not permit a discussion of each of these, but we can quickly recount a few of the facts and concepts which we considered in our efforts to understand Harvey Heckler and his learning needs.

Q4

We noted individual differences not only with respect to the stable differences in intelligence but also with respect to such changeable factors as motivation, maturity, etc. We considered the role of reinforcement in learning and retention and the absence of reinforcement in the phenomena of extinction (an active "erasing" process which we were careful to differentiate from forgetting). We distinguished between repeatable knowledge and useful knowledge, the latter of which is noted by observations of transfer of training (defined as the effect of previous learning on a new activity). Because the effect of previous learning could be both helpful and detrimental we identified both positive and negative transfer and saw that transfer is facilitated by similarity of the new to the old situation and by the generalizability engendered by the old situation. We noted the importance of practice in learning, both massed and distributed. Within the context of simpler forms of learning we considered the role of interference on the rate of learning and distinguished between retroactive and proactive interference. For the development of concepts we discerned the importance of generalization with respect to both stimulus and response. We identified motivation with a state of disequilibrium within the organism (hunger, fear, sex, etc.) giving rise to some need which directs behavior toward some goal. We saw that man not only shares the basic drives of lower animals but that he acquires or demonstrates a variety of other needs - - for affiliation, status, achievement, acquisition, etc. We saw the role of external influences on behavior (incentives) and considered the establishment of a mental set (or appropriate attitude and predisposition for a given task).

These and other items were new to some of us and certainly all confusion has not been dispelled. This is not so critical if there has been developed a sensitivity for the complexity of the learning process, a humility regarding our understanding of it, and a desire to gradually deepen our knowledge and insight. This I believe has been achieved - - we go away with an increased realization that if we're going to teach Harvey and his classmates it will help to know what makes them tick.

III. Selecting Learning Objectives

Knowing how our students learn and what they can learn does not answer the question of what they should learn. Therefore, we considered the subject of learning objectives on a number of occasions and from a number of different points of view. The following were some of the ideas which emerged.

Perhaps most important of all was the repeated emphasis on operational objectives which were contrasted with the meaningless statements which can neither be disputed nor implemented. Objectives are framed in operational form when it is possible to use them in devising appropriate learning situations as means for achieving the objectives and when it is possible to identify the proper "instruments" to discern progress toward these learning objectives.

Another important concept is centered about the notion of a hierarchy of objectives. We were reminded that each level of an educational enterprise has its own particular form of objectives and when it is possible to identify the proper "instruments" to discern progress toward these learning objectives.

Another important concept is centered about the notion of a hierarchy of objectives. We were reminded that each level of an educational enterprise has its own particular form of objectives which get increasingly specific as we proceed from the objectives of the entire institution to the objectives of a single period of a single course. We considered objectives of a single lesson plan, of a complete course, and of an entire curriculum. Naturally we did not have time to refine a specific scheme of objectives but I believe that it was clear that the statements of objectives at the various levels should be mutually consistent and form a network of interrelated learning goals.

From a consideration of this network of objectives there emerged in a number of sessions an important by-product - - the concept of the variability of objectives. While the curriculum of a given department might have a list of a dozen objectives (not all necessarily equally important) it would not be expected that every course within that department would reflect all of the objectives of the entire curriculum. Indeed, a given course might concentrate only on two or three, the only requirement being that the objectives be clearly compatible with the overall objectives. Similarly, the objectives of a given course are not all given equal stress in every class period thereof.

Judging from the extra evening session on objectives and from the vocalized interest in a discussion of objectives I think it is clear that this Institute generated a growing appreciation of the fact that we educators sometimes operate our programs on a non-operational set of objectives and indeed perhaps even a non-verbalized set (so that only by observing our activities could someone infer what we are up to).

Knowing that our objectives must be operational, consistent, and varied does not help us identify their specific nature. In some of the prepared papers (I recall, among others, those of Tyler and Hawkins) and in our discussions there were some references to the forces and issues which enter into the value judgments that are made in deciding that certain objectives are preferred over others. Thus, Hawkins cited the influences exerted by the nature and needs of the engineering profession (as manifested through employers, former graduates, and professional organizations - - ASEE, ECPD, etc.), by the general public, by the international situation, etc. In a slightly different context, Tyler referred separately to the need of the student himself, to the need of a democratic society for intelligent citizens, and the need of the profession for specialized practitioners. Again, in a short institute of this sort, no attempt could be made to develop a full-blown philosophy of engineering education but it was possible to demonstrate both the importance of such a philosophy (if engineering education is not to flounder without direction in these rapidly changing times) and the difficulty of logically and systematically developing it.

IV. Devising Learning Situations

In this area I believe that the Institute achieved success in a number of ways. Having shifted our emphasis from "teaching" to "promoting learning," we enthusiastically re-examined the various practices by which we have taught (and been taught) in order to ascertain whether or not our practices have been consistent with our professed objectives and with our knowledge of how students can best learn the things we expect of them.

Thus we considered in some detail such learning situations as the lecture, the discussion, and the laboratory, Mentioned (but less thoroughly explored) were such things as the tutorial relationship, field trips, the recitation session, seminars, etc. Observing the zest with which all entered into the various workshops in these areas I am confident that all of us will return to our teaching duties and critically review the methods we have employed in order to see whether or not we've been trying to teach concepts in a situation best suited for developing attitudes or skills, etc.

Considering the variety of learning situations which we might employ, we reminded ourselves that the choice depends not only upon the objectives to be achieved but also upon the maturity and previous learning of the students and especially upon our own abilities. We realized that there exist among us individual differences with respect to our abilities to "lead" an unstructured discussion, to inspire 300 students with a lecture, to tutor students, to guide discovery in the laboratory, etc.

In this same area of devising learning situations we considered a number of techniques for optimizing our effectiveness as instigators of learning activities in our students. We considered and practiced the techniques of effective oral presentations. By making slides and transparencies we learned how little time and expense are involved in exploiting these types of audio-visual materials. We got new ideas regarding the potentialities of movies. We made careful lesson plans and practiced our performances on each other. The teaching machine and its possibilities were investigated. While honest differences of opinion probably remain regarding the relative importance of these matters. So, there was ample evidence that each would return to his teaching duties with an increased motivation to improve his techniques and to remain prepared to exploit devices (movies, slides, teaching machines, etc.) which can assist him in maximizing the interaction of the students with the material to be learned.

V. Evaluating Learning

Although we considered tests as devices for promoting learning as well as for measuring it in view of the fact that most of the discussion seemed to revolve around the evaluation of learning, I am taking the liberty of separating this topic from the foregoing section dealing with the devising of situations for promoting learning.

Having already refined our notions of the array of different types of learning expected of our students we were prepared for a frank and productive discussion of the various ways of measuring student progress toward these learning objectives. To an outside observer such as myself there was a marked change over the course of a single day devoted to testing. Among other bits of evidence of this were the products of the workshops.

First of all, a number of groups exhibited a genuine willingness to consider the possibility of increasing the effectiveness of our measurements by using such things as essay questions, matching items, true-false questions, etc. This trend toward different types of questions seemed to reflect not so much a desire for variety for its own sake as it reflected a realization that a given course might have among its objectives the learning of such different things as problem-solving skills, definitions, facts, etc., in which case the "standard" examination consisting only of problems might not be appropriate.

We increased our understanding of such concepts as validity and reliability. We distinguished between relative and absolute grading systems, and got down to some bed-rock questions in connection with the use of the normal curve, especially in senior and graduate courses or in honor students. We learned that except for the psychological value of an easy opening question best descrimination among student achievements is obtained if test items are all about the same level difficulty - - such that about half of the students get less than half-credit on the question.

VI. Conclusion

Although I have not commented explicitly on each paper in this summary I hope it is true that the foregoing can serve as a conceptual framework about which you can organize your own synthesis of your experience at this Institute. As I indicated earlier I am reserving for our final meeting certain material which I believe can be presented more effectively in such a context. Specifically I shall outline insights and relationships which have occurred to me during these two weeks. Were I to have included these more individualistic interpretations in this paper, I might have needlessly channeled your reflections prior to our last session thereby possibly robbing you of the experience of developing your own new insights.

Your attention has been focused for the past two weeks on how you facilitate learning in your students - - deciding upon the different types of learning you wish to promote (principles, concepts, skills, attitudes, facts, etc.), devising learning situations best suited for achieving the various learning objectives, and designing appropriate instruments for measuring these forms of learning. As a final exercise it might be profitable for you to step back and take a detached view of this Institute where your role was that of a learner. What kinds of learning (concepts, skills, attitudes, facts, etc.) were the presenters trying to achieve with you? Can you analyze your learning into these or some other set of categories? Upon reflection, did the presenters devise appropriate conditions for effective learning? Such detached reflections should provide ideal preparation for a fruitful critique and the final summary session.

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- "Technological Education at Carnegie"
- "The Interplay between Liberal and Professional Courses in a College of Engineering and Science"
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American Council on Education. Booklets published periodically.

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Improving College and University Teaching, ed. D. M. Goode, The Graduate School, Oregon State College, Corvallis, Oregon, $2 per year. An international quarterly featuring articles written by college teachers. Illustrative articles:

"Some Questions on College Teaching," Tead, Ordway, February, 1954. A series of questions designed to make the reader think about the breadth of his responsibilities in doing good teaching.

"My Favorite College or University Teachers," November 1955. Twenty-six (26) graduate students describe with sincerity the college teacher who made the deepest impression on their lives and why he seemed to do so.

"Student Ratings of Faculty," W. J. McKeachie, Winter, 1957. A psychologist briefly reviews the main findings of 30 years of research in this field.

"Aims in College Teaching and Learning," M. Savelle, Winter, 1957. A history professor sees the reciprocal aims of college teaching and learning as having for their ultimate objective the education of the whole individual mind.

"The Role of Role Playing," C. E. Buxton, Spring 1957. A psychologist discusses role playing as a method of achieving certain specific objectives.

"The Teaching of Science Teachers to Teach," C. Suskind, Spring 1957. An electrical engineer discusses ways of using skills in teaching in the training of college teachers.

"Is Teaching a Profession?" M. S. Marshall, Autumn 1957. A microbiologist explores the implications and obligations of the term "professional."

"Inquiry into Inquiry," W. R. Hatch, Autumn 1957. A biologist discusses the relationship of the professor's investigation task to teaching. The spirit of inquiry should also be evident in the student's learning. In subsequent articles he indicates how this spirit of inquiry infuses vitality into lecture, laboratory, dialogue, and examination.

"The Students' Faculties," M. S. Marshal, Winter 1959. A microbiologist directs the professor's attention to thinking in terms of student's thoughts, experiences, problems, and goals.

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"Notes on 'How to Improve our Engineering Curriculum,'" R. K. Bernard, April 1954. The author finds clues for improvement by comparing the European method of teaching with the American.

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"Some Modifications in Approach to Teaching Engineers," E. C. Shuman, January 1947. An industrial research supervisor criticizes engineering teaching and suggests a different approach.

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"On Teaching Engineering Teachers to Teach," C. Susskind, December 1957, An assistant professor of engineering discusses a program designed to improve the teaching of engineering.

"The Use of Problems and Instances to Make Education Professional," B. R. Teare, November 1948. Duscusses the need for problem-solving in the training of the professional engineer and suggests ways in which this may be done.

"What the Technical Teacher Can Do to Improve Training in Writing Skills," C. K. Arnold, November 1957. Criticizes lack of ability of engineers in writing and gives suggestions for improvements in Engineering colleges which will train engineers to write accurately, forcefully, concretely, and interestingly.

"The Engineering Profession in a Society in Transition," A. H. Blaisdell, November 1946. The real importance of effective instruction in our society.

"Some Effective Methods of Teaching Mathematics," W. C. Krathwohl, October 1948. The application of these principles may be used in many fields.

"Professors vs. Engineering Education," November 1946. An industrial metallurgist discusses faults of faculty members in failing to prepare students adequately for service in industry.

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Smith, O. H., "Experience Plus Realization," American Journal of Physics, May 1950. The recipient of the Oersted Medal for Notable Contributions to the Teaching of Physics discusses his ideas about many phrases of teaching.

II. Specific References

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Seagoe, M. V., A Teacher's Guide to the Learning Process, William C. Brown, Dubuque, Iowa, 1956. This book translates the theories of learning to classroom practice and enables the teacher to utilize these to increase his effectiveness. The findings of research are applied to specific situations. An extensive bibliography is organized in such a manner that the teacher may select the readings related to a specific problem.

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On Colleagues and Clients
Address of the Oersted Medalist
AAPT-APS Ceremonial Session
Promenade Ballroom, Manhattan Center, New York
by Paul Kirkpatrick

Thank you, Professor Eaton and President Overbeck. I haven't often been honored by a two-stage introduction and certainly never by one so eloquent, so specific, or so favorably biased. I think, ladies and gentlemen, I have never before been awarded a medal, either for heroism, good conduct, great achievement, or academic fortitude. The Oersted medal - at its best - calls for a measure of all four qualifications, and I never have thought of myself as a fit candidate for it. I have served the American Association of Physics Teachers in various capacities but wouldn't think it right for the officers of the Association just to give prizes to each other.

Now, before I convince everybody here that the current award was a mistake, let me change the subject and speak for a few minutes about the teaching physicist in his relations with certain groups of people who assist or obstruct his work.

Across the campus from where you and I work there is a school of education, or maybe a department. We hear that it is there but we don't visit it very often. We are trying to teach the young and realizing that the job is too hard for us. Probably there isn't a teacher here who feels that he is a complete success. But while we go on with these feelings of partial success there is nearby this company of specialists in the philosophy and technique of the teaching process, and we make no use of them. When we are stuck on a chemistry problem we go to the chemists; if we get beyond our depths in mathematics we know mathematicians who will throw us a rope. Physicists in my home department, on one occasion, were broadminded enough to seek aid at the department of classic languages, and they came home with their problem solved. In that conference the work "klystron" was invented. But when we are wondering how to educate we do not go to the educationists. Do we feel that they do not have the answers or do we avoid them so as not to incur guilt by association?

I cannot dismiss this odd boycott, as some apparently can, by declaring that ninety percent of the educationists are fools led by the ten percent who are smart rogues. I know some educationists who seem to be as intelligent as physicists and as honest as mathematicians. They do not exalt pedagogical know-how above factual know-what. They don't take pride in producing highly trained but ignorant teachers. They worry about some of the same educational problems that bother me, but with a better background in these areas, they worry better. The best of them will agree that many educationists have been bumptious and arrogant, and that their fast-growing field has suffered from quackery and charlatanry. But unless their whole discipline is fraudulent - which I do not believe - the rest of us do harm to our own disciplines by exchanging epithets with educationists or by pretending that they don't exist. I think that sooner or later teachers of all sorts are going to have to agree that there is some kind of scientific basis possible for what they are trying to do, and I wish we were getting ready for that time now instead of pulling away from it.

Now don't imagine that this pure company is being infiltrated by a disguised educationist. I have muddled along for forty years without the benefit of a course in Education but I am not as proud of my ignorance as most science teachers are. Whether or not the educationists know the answers, they deal with great questions. What is the real nature of the process of learning? How can one train the mind? Can people be taught to think, and if so how do you do it? To what teaching operations are the different types of students susceptible, and how are the various types to be recognized? Everyone who teaches needs the answers, even the man who is a "born teacher," whatever that phrase means. If we do not trust the putative authorities should we not be doing something else about this need? I think we are in a drifting condition. The American Journal of Physics prints much about apparatus but less about how to instill the lessons of the apparatus into the student mind. We print good expository articles on physics as a science but little that is basic about transmitting that science to the customers before us. I am sure this lack is not the result of the editorial policy; it occurs because you and I and the others who write for the Journal do not at present know what should be said on these matters.

Now I can almost hear the grumbling in the back row where somebody just said, "When the American Journal of Physics becomes a journal of pedagogy they will have to get along without my subscription." I hope I did not hear that ancient slogan of the anti-educationists, "All a teacher needs is to know his stuff." People who talk this way are logically as vulnerable as their opponents in the opposite corner who say, or have been said to say, "All a teacher needs is to know how to teach." Let's not do battle with ridiculous weapons. Knowing your stuff is necessary but not sufficient. Teaching is a matter of operations - you do certain things - and the omniscient professor who does the wrong things or does nothing, is not teaching. We are not going to find out what the right things are, I should suppose, by shallow empirical deductions. We need basic theory and should at least sympathize with honest people who are trying to develop it even though they could not claim that they now have it ready for our use.

All right, they don't have all the answers. They have a few, and when the fuller answers come I think it likely that they will come to scholars of competence who are looking for them, rather than to those who are contemptuous of the whole quest and of all men who engage in it. I am really commending not a group of individuals but an attitude toward the eventual possibility of finding out how our job should be done, and I don't think we know how at present.

Now a part of the aversion that natural scientists feel toward educationists springs from some fear that educationists may manage to get control of the licensing of college teachers and compel us, or our successors, to undergo training under them. If this were a real threat it would be something to fight against, but I can't see any prospect at all of such a requirement. There is at present no move on foot among educationists anywhere in America to bring this about.

If I were at the start of a teaching career instead of a few weeks from the end of one I should at least try to base my methods upon rational foundations rather than upon traditional practices of the teaching guild, imitation of my own teachers, or selective adoption of methods that seem to get by.

In accepting this award I am in the position of the veteran wheel tapper who was tendered a banquet and given a gold watch on the occasion of his retirement after forty years of faithful service. You've probably seen this important employe in the railway station yard, walking along beside the standing train with a peen hammer in his hand and tapping the wheels, listening acutely for the rare cracked wheel which, if undetected, might cause a serious accident. There was one man at the dinner who didn't understand what it was all about, so afterward he sought out the tapper emeritus and asked him, "What was the purpose of tapping those wheels?" The retiring veteran answered, "I don't know. They just told me to tap 'em."

I hope no one collars me after this session and asks the purpose of every teaching technique I have used during these many years. I could not justify them in detail, but I hope that teachers will not always have to proceed in such uncertainty.

The second group of professional neighbors that I mention today is that of the research people. Of course a research man is often a teacher with his research hat on, but there are many teachers who do not possess such a hat, and there are many research men around our universities now who have no teaching responsibilities. I'm concerned with the interaction of these two activities in a university or college, and with how they aid or obstruct each other. This is a fairly modern problem, for research was not uniformly supported by American universities until the present century. Let me say a word about the history of this subject. Today research is so generally accepted as one of the great natural functions--if not the main function--of any institution granting higher degrees that the young men here--those under sixty, that is--may find it hard to realize that for centuries universities were just places where teachers taught students. Even in the later nineteenth century eminent presidents Eliot of Harvard, White of Cornell, and Gilman of Johns Hopkins declared that teaching was much more important than investigation, a proposition which at that time was denied nowhere except at the University of Chicago.

But the spirit of research was stirring, and the American Physical Society came to birth right along with the new century. That organizational step was brought about mainly by teachers who wanted to do research, not by the pressures of already abundant research production looking for an outlet. Professor Ernest Merritt, the first Secretary of the Society, once told me that shortly before each APS meeting he used to have a hectic scramble getting together enough contributed papers to round out a program.

It's my impression that the present Secretary rarely has to do this. At any rate in the early decades of this century most of the research in physics in America took place in educational institutions, not in the laboratories of industry or government.

Although the Physical Review was being written by teachers it was only a small minority of the teachers who were doing it. This great new function of research in the universities came along slowly, partly because it was expensive and took staff time, but more because faculties included no great corps of trained enthusiasts for such work. Rowland had said, "You don't need money, you don't need time; all you need is to want to do it." But half a century ago all three favoring commodities (money, time, desire) were in short supply. The leading enthusiasts were the young physicists home from Europe with their dazzling German Ph. D. degrees, but they were few in number for a big country.

Here a little and there a little research came into the universities and it would be ridiculous to claim that it did not compete with the teaching function. It is told that when Michelson was asked how he managed to get so much good research done he replied, "By neglecting my students." (That's a practice that did not die with Michelson.) Now it is the undergraduate student who suffers in such cases. I think that close association of an advanced student with a strong research man can be highly educational in an unsystematic way, quite apart from any conscious didactic operations. It is an apprenticeship. It was even said at Chicago that the best training for a graduate student was to carry water for Michelson. The effect is not precisely teaching, and it is not available in wholesale quantities but it is good so far as it goes. Some of the greatness of Socrates seems to have rubbed off on his student, Plato, and it was not transferred by the lecture system for Socrates didn't believe in the lecture system. But it does an undergraduate little good to sit in the presence of a scientist of reputation unless the great man says or does instructive things. This he may or may not do, like any other teacher.

When teaching moved over to make room for research - around 1900 and thereafter - some educators and scientists who believed strongly in both activities tried to play down the mutual interference effects. These coexistentialists were heard advancing three propositions, and I repeat them.

First, every good research man is _ipso facto_ a superior teacher.

Second, it is not possible for a non-research man to be a superior teacher.

Third, the partnership of research and instruction is always mutually beneficial.

I don't think that these assertions were inductions from any real observations; they were, I believe, just articles of faith, adopted, not derived. I am afraid the weight of the observations is against them all, but they were attempts - wistful perhaps - to deal with a real problem which is still unsolved: the problem of promoting the mutually helpful coexistence of instruction and investigation in science.

Since these three claims may still be heard occasionally, we will take a closer look at them. The first one was strongly worded by President David Starr Jordan, who said, "I very much doubt if any really great investigator was ever a poor teacher." Seemingly President Jordan had not heard of the case of Willard Gibbs, who is said to have failed so completely as a teacher at Yale that there was a movement to replace him. We have all been graduate students, and most of us can remember sitting before at least one honored - and justly honored - research scientist who for one reason or another was unsuccessful in the classroom. Possibly he didn't care for people; perhaps he was just naturally inarticulate; it may be that he was bored with teaching and considered it an unimportant part of a job that he had accepted mainly to be able to do his research. Fortunately a scholar of this type no longer needs to suffer in the classroom. Not the physics classroom. He can now get a better job requiring the full-time use of his highest talents.

I am not suggesting that there is any negative correlation between effectiveness in research and in teaching, but only that the positive correlation is a long way from unity. The brilliant critic Jose Ortega y Gasset wrote, "I have lived close to a good number of the foremost scientists of our time, yet I have not found among them a single good teacher." To me this is incredible testimony. I have also lived close to some top scientists and I am sure there were top teachers among them, judged according to any definition or test you might devise.

I turn to the claim that a man not doing research, or not eager to do research, can never be a superior teacher. The affirmative argument holds that one never really understands the inwardness of physical phenomena, the treachery of glib but plausible explanations, never grasps the reasons behind the reasons until he digs clear to the bottom of extant knowledge and then a little deeper. This argument sometimes maintains that book learning is fine if you want verbal knowledge, but research people are doers of the word and not hearers only. The superior teacher should have buried himself in the physical mysteries and drawn out the truth with eyes, ears, tactual nerve endings and the sense of smell.

Now I do think that experience in research has improved many a teacher's comprehension of the nature of science and greatly deepened his understanding of specific problems. But science is long, life is short, and research is narrow. There is not time enough to master the whole of physics through direct research experience, and the detailed insight that a man has time to secure in this way will rarely be passed on to his students unless he is giving a seminar in his research speciality. Any teacher of a general physics course who devotes more than fifteen minutes of lecture time to his own research may be suspected of egotism.

I am worried about how the intensive research specialist finds time to understand the rest of physics. Nowadays we have a class of bright young Ph D.'s who have managed to become familiar with the inside of a nucleus but are ignorant of the inside of a voltmeter. As teachers we all need perspective. We need to know where the frontier of physical knowledge lies and how the fight for its expansion is going on in the various sectors. A man who is intensely preoccupied with the tactics of one sector may have less chance to see the whole situation clearly than will an equally earnest and intelligent man who pulls out of the fight and merely studies it from headquarters.

This, after all, is about what the theoretical physicist does. Instead of performing experiments he reads and thinks and talks about the experiments of other people. Surely we have theorists who have gained an enviable comprehension of physics by this process, and I doubt that you can find an experimentalist so well informed as to feel superior to them all. The method of the theorist - that is, mastering science by reading literature instead of meters - is open to every teacher who lives near a library, to the degree permitted by his mentality, his temperament, and of course his time commitments. If his thinking leads him to formerly unrecognized truths, then he is a research man, but his teaching is benefitted whether his study has this by-product or not. The teacher who chooses this method of learning has no reason to feel - I should say - that his colleague who reads meters has a superior pipeline to the sources of enlightenment.

To point out that many research men are superb physicists and draw the conclusion that the doing of research per se made them that way is to commit a logical fallacy too elementary to dissect before this audience.

Now a word about the third axiom that I quoted - the statement that the association of instruction and research necessarily benefits both. It is easy to point out that each depends upon the other, for it was research that gave the teacher something to teach, but without the teacher's support research would die out tomorrow for a lack of trained workers. Yet beyond this broad interdependence some individual scientists have found the combination advantageous in their own lives. Hans Christian Oersted, whom we are remembering today, discovered electro-magnetism while in the very act of demonstrating before an audience. Sir J. J. Thomson writes in his autobiography that the bright, inquiring minds of students kept him from settling into fixed mental postures, while their questions sometimes stirred him to think thoughts conducive to discovery. Well, everyone wishes it might always work this way, but does it? I think not. In the life of a university department the interests of research and of teaching are competitors. I don't mean to say that people within a department must necessarily engage in controversy with each other in the promotion of these rival activities, though this may happen. I just mean that the activities themselves are in necessary conflict in any department which thus seeks to serve two masters. These activities compete for room space, for the working time of staff members, including mechanicians and secretaries, for funds, and for the control of faculty appointments.

If you will pardon my own unimportant case history, I got into research in the era of love and string and sealing wax. I outlived the string and the sealing wax but love lingers on. In my experience the demands of research and of teaching have been in continual conflict for nearly forty years, and I cannot remember that either function ever helped the other. Many a demonstration would have been better prepared and many a student better served if the urgency of some situation in the research laboratory (and the fascination of it) had not pulled in that direction. On the other hand, the continuous concentration that a research dilemma can demand was often broken up by the class bell. I would have done better at either one of these activities if I had kept out of the other, and I suspect that there are hundreds of scientific men who could give the same testimony. This is not a situation that we can take any satisfaction in but is just one of the facts of academic life.

To get the American universities solidly into research required some slighting of the teaching function, as I said earlier. President Harper at Chicago announced that the promotion of faculty members ". . . will depend more largely upon the results of their work as investigators than upon the efficiency of their teaching," thus reversing the policies of great presidents of the preceding generation. President Harper's declaration seems a wide-open invitation to the faculty to neglect their students, and a justification of Michelson's method. I believe the Harper policy (supremacy of research) is now in effect, practically speaking, in nearly all the large universities of this country, though in some of them the public statement is made that teaching and research are treated as equals. As a matter of fact, presidents and trustees, whatever their statements, cannot control such policies; these issues are managed at the departmental level, where the real work is done and where requests for appointment and promotion originate. Anyway, for two generations now university research has received indulgent consideration and its prosperity has been paid for in part by other university functions. Perhaps that's the only way it could have been established. I don't know. Like an infant industry, research has benefited from certain protective tariffs. Well, it is no longer an infant - in physics at least, and it is in no need of further protection. When D. L. Webster went to Stanford forty years ago he surveyed the university junk yard for raw material before planning the details of his research equipment. Now the same department has in the planning stage one research project whose budget may equal that of the entire present university. There was an infant that grew up.

It does seem that it is high time to swing the protective tariff back from the researchers to the teacher as teacher. We don't need to go clear back to the nineteenth century, but perhaps to a status appropriate to the needs and conditions of our times. First among these conditions is the fact that research in physics now has its cloud of ministering angels, but there are some additional, supporting considerations. The switch to the aid of teaching I suggest is due at the several levels of physics teaching because no one seems to want to teach physics in the high schools, because the instruction offered in colleges and universities is not attracting enough specializing students to meet the public need, because recruitment of well-qualified physics teachers for colleges and universities has become very difficult against the competition of better-paying employers, because universities are unable or disinclined to train teachers for colleges, and because industries are now able to recruit physicists right out of college and university faculties.

Now it seems to me that there was one other category of people that we deal with. Oh, yes, the students. These are our best customers, and I don't see how we could ask for better ones; they crowd in upon us with their immense demand for our product, they pay their money and accept what we give them - most uncritically - and they seem especially pleased when we give them short weight. I mean I know of no case in an American college where the students have protested the announcement of a holiday or where they have organized a demand for longer and harder problem sets. That can't happen here.

I believe that in many universities and institutes we have been taking advantage of the student's poor business sense and giving him less than his money's worth. I am thinking of the institutions of high repute where a part of the teaching - indeed, the most direct and personal part of it - is entrusted to amateur teachers and often to absolute beginners. This is the unmentioned skeleton in the closet of higher education. Most of our students have come up from childhood without ever being placed under the care of an untrained teacher until they begin to meet such in university physics and chemistry laboratories and quiz sections. Uncritical as students are, some of them do think it strange - and they have told me so - that they have had only trained and experienced teachers in the free public schools but some teachers who were complete novices in prestigious high-tuition institutions.

If you think of a laboratory instructor as only a proctor who keeps order in the room where a group of students are pursuing their independent work, then of course you will see no objection to turning the job over to a first-year graduate student. But I see in the laboratory one place in the physics course where student and teacher become acquainted; the place where the teacher can dispense his merchandise at retail or (in a different figure) where he can prescribe for his patients as individuals who may be suffering from slightly different complaints.

There are many teachers here who are quite outside the system I am criticizing, for many liberal arts colleges do not have any graduate students around, and therefore the teachers have to do the teaching. I have long felt that this is a real point of superiority for the four-year colleges, and it may have had something to do with the demonstrated ability of some such institutions to surpass big universities in the preparation of students for graduate training in the sciences. But in some of the colleges one can find the still weaker practice of using undergraduate students (seniors) as teachers.

Teaching assistantships in physics used to be justified as a means of subsidy for the graduate students. It is not certain that the tuition-paying undergraduate would go along with this defense, but it is certain that the graduate student of today does not need this assistance as greatly as did his predecessors. There has been a vast increase in the number of agencies competing for a chance to aid him. Is it too much to hope that the universities will some day relieve the graduate student of his teaching duties, put a better-qualified teacher in his place, and then - in case the graduate student really wants to learn about college-level teaching - do something serious about training him?

I have called the student first a customer and then a patient, but I really think of him as a client. We do not impersonally market a product nor do we impose a professional prescription that the recipient is bound to swallow without question. We offer counsel that the client may be persuaded to act upon. If the counsel is to be good it needs no emphasis that the counselor must be learned and in a state of ever-increasing learning. But getting the client to respond and comply requires a professional relationship that I shall call rapport. It is about as important to the teacher's success as is his knowledge or his apparatus. It becomes more difficult to achieve this rapport as enrollments go up. For the master with a few disciples, rapport is easy; for the radio or TV teacher it is impossible. Most of us stand somewhere in between. Rapport means knowing the state of ignorance of the student, and of the class, so that one does explain the obvious nor yet the incomprehensible. A teacher must sense what goes on in the minds of his students or he will not know what to say to them. Rapport means knowing the student's question as soon as he opens his mouth to ask it. When we are greatly surprised by the results of an examination, finding that the class has done far better or worse than we expected, we stand convicted of faulty rapport. We should have known what they would be able to do. When we are astounded by a student's ignorance we reveal that we have not been on the job, and the teacher who indulges in sarcasm about a student's studpidity is unnecessarily exposing his own.

Once upon a time a university known to me invited a learned man to serve as visiting professor, and after a few weeks it became evident, through student complaints, that the visitor's lectures were not going over. The department head then discussed the situation with the visitor and suggested that he adjust his presentation to the immaturity or inadequate preparation of the class. The visiting professor took the suggestion as an affront to his honor, and with a show of dignity he said, "What you ask is impossible! I have standards."

Here was a case where, with the highest of intentions, a teacher addressed himself to a class which existed only in his own imagination, and consequently he never achieved any harmonious contact with the real people sitting before him. Ever since that experience that department has checked every candidate for appointment to make sure that they don't appoint another man who has standards. Standards, they will tell you, are something to be kept in the National Bureau.

One might go on and discuss the contacts of the teaching physicist with other groups - administrators, the government, the public - but time would not permit.

Finally, I ask your pardon for the many statements which should have been preceded by the words, "It is my opinion that . . ." To save time that phrase was omitted but it does not mean that I have a high opinion of all my opinions, for I find that impossible. When exact scientists voice their views in the debatable areas of the arts or of human relations they need to be guided by the three classic rules for courting a woman, of which, as you may recall, the first is, be bold. The second rule is, be bold; and the third is, be not too bold.

This award which brings me to the platform today is an extremely gratifying thing to any recipient, whatever misgivings he may have about the merits of it. I do want to record my deep appreciation and thank this large and kind audience for the loan of its ears.